This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

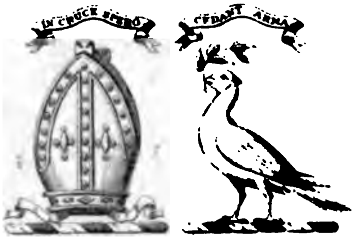
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

Stanford University Libraries
3 6105 007 664 2



Francis Hubert Barclay

W. H[illegible] Ltd.
Booksellers, [illegible]
Camb[illegible]

BRANNER
GEOLOGICAL LIBRARY

STANFORD UNIVERSITY LIBRARIES

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

VOLUME THE TENTH.

1887-8.

EDITED BY

G. S. BOULGER, F.L.S., F.G.S.,

Professor of Geology in the City of London College.

(Authors alone are responsible for the opinions and facts stated in their respective Papers.)

STANFORD LIBRARY

LONDON.

1889.

499919

Lewes:
SOUTH COUNTIES PRESS LIMITED.

CONTENTS.

PAGE

Ordinary Meeting, November 5th, 1886 1

On the Erosion of the Coasts of England and Wales. By W. TOPLEY, F.G.S., Assoc.Inst.C.E., H.M. Geological Survey. (*Title only.*) 1

Ordinary Meeting, December 3rd, 1886 2

On "Leathery Turtles," Recent and Fossil, and their Occurrence in British Eocene Deposits. By A. SMITH WOODWARD, F.G.S., of the British Museum (Natural History) 2

On some further Researches in Bone-Caves in North Wales. By HENRY HICKS, M.D., F.R.S., F.G.S. 14

Ordinary Meeting, January 7th, 1886 18

On Crinoids and Blastoids. By P. HERBERT CARPENTER, D.Sc., F.R.S., F.L.S. (*Illustrated.*) 19

Annual General Meeting, February 4th, 1887 29

Annual Report 29

Ordinary Meeting, February 4th, 1887 38

Ordinary Meeting, March 4th, 1887 39

A Revision of our Lower Eocenes. By GEO. F. HARRIS, F.G.S. ... 40

Ordinary Meeting, April 1st, 1887 58

The Metamorphosis of Basic Igneous Rocks. By J. J. HARRIS TEALL, M.A., F.G.S. 58

Ordinary Meeting, May 6th, 1887 79

Ordinary Meeting, June 3rd, 1887 79

The Formation of Agates. By W. J. LEWIS ABBOTT 80

Ordinary Meeting, July 1st, 1887 93

On the Geology of Cornwall. By J. H. COLLINS, F.G.S. 94

Notes on the London Clay and its Deposition. By J. STARKIE GARDNER, F.G.S. 115

Visit to the Historical and Type Collections in the Geological Department, British Museum, March 12th, 1887 123

Visit to the Doulton Potteries, at Lambeth, March 30th, 1887 ... 130

Easter Excursion, 1887.—Preliminary Excursion to Southampton ... 132

Excursion to Brighton and Newhaven, April 11th and 12th, 1887 ... 141

Excursion to Whetstone and Finchley, April 23rd, 1887 145

Excursion to the Brent Valley, Dollis Hill, and Hampstead, May 7th, 1887. (*Illustrated.*) 148

Excursion to Merstham, Redhill, and Reigate, May 21st, 1887 ... 154

Excursion to Cirencester and Minchinhampton, May 30th and 31st, 1887. (*Illustrated.*)... 157

Excursion to Rickmansworth, June 4th, 1887 163

Excursion to Aylesbury, June 11th, 1887. (*Illustrated.*) 166

PAGE
Excursion to the Mount, Ealing, and Horsington Hill, June 18th, 1887. (*Illustrated.*) 172
Excursion to Gomshall, Netley Heath, and Clandon, June 25th, 1887 182
Excursion to Sudbury, Suffolk, July 9th, 1887. (*Illustrated.*) ... 187
Excursion to Plumstead and Bostal Heath, July 16th, 1887 191
Excursion to Sheppey, August 1st, 1887 194
Excursion to Cornwall, August 8th to 13th, 1887. (*Illustrated.*) ... 196
On the Unmaking of Flints. By Prof. J. W. JUDD, F.R.S. 217
On the Formation of Rounded Flint Pebbles. By J. LOGAN LOBLEY, F.G.S.... 226
Ordinary Meeting, 4th November, 1887 233
Fifty Years' Progress in British Geology. By F. W. RUDLER, F.G.S., President 234
Ordinary Meeting, 2nd December, 1887 272
A Synopsis of the Vertebrate Fossils of the English Chalk. By A. SMITH WOODWARD, F.G.S. (*With Plate I.*) 273
Ordinary Meeting, 6th January, 1888 339
On the Occurrence of Gold in Wales. By T. A. READWIN, F.G.S. (*Abridged.*) 339
Annual General Meeting, February 3rd, 1888 345
Ordinary Meeting, February 3rd, 1888 354
Ordinary Meeting, March 2nd, 1888 354
Notes on the Pleistocene Land and Freshwater Mollusca from the Barnwell Gravels. By B. B. WOODWARD, F.G.S. (*Illustrated.*) 355
Ordinary Meeting, April 6th, 1888 361
On the Discovery of Elephas primigenius, associated with Flint Implements, at Southall. By JOHN ALLEN BROWN, F.G.S., F.R.G.S., &c. (*Illustrated.*) 361
Influence of Geology on the Early Settlements and Roads. By F. J. BENNETT, F.G.S. 372
Ordinary Meeting, May 4th, 1888 385
On Palæozoic Arcidæ. By J. LOGAN LOBLEY, F.G.S.... 385
Notes on Pterodactyls. By E. T. NEWTON, F.G.S. (*Illustrated.*) ... 406
Ordinary Meeting, June 1st, 1888 424
Some Observations on the Natural History of Gypsum. By J. G. GOODCHILD, H.M. Geol. Survey, F.G.S., F.Z.S., M.B.O.U. ... 425
Ordinary Meeting, July 6th, 1888 445
The Clays of Bedfordshire. By A. C. G. CAMERON, H.M. Geological Survey 446
Visit to the British Museum (Natural History) Department of Geology, Saturday, March 17th, 1888. (*Illustrated.*) 457
Visit to the Natural History Museum, Botanical Department, Saturday, April 7th, 1888... 468
Excursion to Wimbledon and Putney, Saturday afternoon, May 5th, 1888 471
Excursion to Charnwood Forest, Monday and Tuesday, May 21st and 22nd, 1888 472
Notes on the Microscopic Character of some Specimens of Rocks collected during the Excursion to Charnwood Forest. By MAJOR-GENERAL C. A. McMAHON, F.G.S. 476

PAGE

Excursion to Laindon (or Langdon) Hills, Essex, Saturday, June 9th, 1888 489

Excursion to Reading, Saturday, June 16th, 1888 493

Excursion to Godstone, Tilburstow, and Nutfield, Saturday, June 23rd, 1888 496

Excursion to Rickmansworth, Saturday afternoon, June 30th, 1888 ... 499

Excursion to Loampit Hill, Lewisham, and West Combe Park, Greenwich, July 7th, 1888 501

Excursion to Bedford and Clapham, Saturday, July 21st, 1888 ... 504

On the lower divisions of the Carboniferous rocks of the Forest of Dean. By E. WETHERED, F.G.S., F.C.S., F.R.M.S. (*Illustrated.*) 510

Sketch of the Geology of the Forest of Dean, with special reference to the Long Excursion. By WINTOUR F. GWINNELL, F.R.Met.S., F.A.S. 522

Notes on the Rhætic Beds and Lias of Glamorganshire. By HORACE B. WOODWARD, F.G.S., of the Geological Survey of England and Wales. (*Illustrated.*) 529

Note on the South Wales Coal-Field. By F. W. RUDLER, F.G.S., President 538

Excursion to the Forest of Dean, Wye Valley, and South Wales, Monday, August 6th, to Saturday, August 11th, 1888. (*Illustrated.*) 542

LIST OF ILLUSTRATIONS.

PAGE
1. Diagram of a Crinoid ... 27
2. Ideal Section of the London Clay ... 116
3. Section from Pinner to Hampstead ... 153
4. Diagram Section from Stroud to Cirencester ... 162
5. Diagrammatic Section, Aylesbury to Hartwell ... 168
6. Section at the Mount, Ealing ... 175
7. General Section of the Great Pit, S. of Ballingdon ... 187
8. Section in Chalk Pit, E. of Sudbury ... }
9. „ of Two Pits, N.E. of Sudbury ... } *Opposite* 188
10. „ in Mr. Green's Pit, N.E. of Sudbury ... 190
11. Crag Ridge in same Pit ... 190
12. Map of Country N. of St. Austell ... 198
13. Section of Carclaze Old Pit ... 199
14. Map of Country between Redruth and Cambourne ... 203
15. Section of Granite and Killas, near Carn Brea ... 204
16. „ at St. Erth, 1885 ... 207
17. Map of Western Extremity of Cornwall ... 210
18. „ the Lizard District ... 213
19. Diagram of Teeth of *Ptychodus* ... 296
20. Plate I.—Cretaceous Fishes ... *Opposite* 338
21. *Clausilia pumila*, Ziegl. and C. *biplicata*, Mont. ... 357
22. Palæolithic Implement from Southall ... 363
23. „ „ „ ... 365
24. „ „ „ ... 365
25. „ Spear-head „ ... 366
26. Skulls of Pterodactyls ... 406
27. *Pterodactylus antiquus* ... 409
28. *P. spectabilis* ... 410
29. *Scaphognathus crassirostris* ... 413
30. *Dimorphodon macronyx* ... 415
31. *Rhamphorhynchus münsteri* ... 416
32. *Pteranodon longiceps* ... 419
33. Skull of *Thylacoleo carnifex* ... 462
34. „ *Bettongia* (*Hypsiprymnus*)... 463
35. Section of Redbrook, Gloucestershire ... 513
36. Section from Lavernock to Penarth Head ... 530
37. Geological Map of the Forest of Dean ... 544
38. Vertical Section of Garden Cliff ... 546
39. Geological Map of Neighbourhood of Cardiff ... 549

CORRIGENDA.

p. 214, line 5, *for* Wüncsh, *read* Wünsch.
p. 220, line 13 from bottom, *for* organism, *read* organisms.
p. 351, line 4 from bottom, *for* Rev. W. Jays, M.A., *read* Rev W. Iago, B.A.
p. 352, line 7, *for* G. Brown Millett, *read* G. Bown Millett.
p. 407, Fig. 7. Dimorphodon is $\frac{1}{3}$ nat. size, not $\frac{1}{10}$, as stated.

PROCEEDINGS

OF THE

GEOLOGISTS' ASSOCIATION.

ORDINARY MEETING.

FRIDAY, NOVEMBER 5TH, 1886.

W. TOPLEY, Esq., F.G.S., Assoc.Inst.C.E., President, in the Chair.

The donations to the library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected members of the Association :—Upfield Green; C. Hansford; R. S. Herries; E. Lloyd Owen; E. Lloyd Owen, junr.; and W. W. Watts, M.A., F.G.S.

The President then delivered his Address, 'On the Erosion of the Coasts of England and Wales.'

It was proposed by Mr. Hopkinson, seconded by Mr. C. J. Alford, and carried unanimously that the President's Address be printed *in extenso*.

Mr. W. Busby exhibited and remarked upon some specimens of fossil leaves and fruits from the Woolwich and Reading Series at Reading.

ON THE EROSION OF THE COASTS OF ENGLAND AND WALES. By W. Topley, F.G.S., Assoc.Inst.C.E., H.M. Geological Survey.

[*Publication deferred.*]

ORDINARY MEETING.

FRIDAY, DECEMBER 3RD, 1886.

W. TOPLEY, Esq., F.G.S., Assoc.Inst.C.E., President, in the Chair.

The donations to the library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected members of the Association:—F. B. Bather, B.A., F.G.S.; A. Champernowne, M.A., F.G.S.; J. Edmunds, M.D.; R. M. Gordon; Miss A. K. Harding; F. Harrison; C. Holme, F.L.S.; Miss J. B. McLeod; C. J. Mitchell, M.A.; Commander C. E. Reade, R.N.; J. P. Smart, junr.; C. N. Peal; T. Simpson; Rev. H. H. Winwood, M.A., F.G.S.; and R. B. Yardley.

The following papers were then read:—'On fossil leathery turtles and their occurrence in British Eocene deposits.' By Mr. A. Smith Woodward, F.G.S.

'On some further researches in bone-caves in Wales.' By Dr. H. Hicks, F.R.S.

Mr. S. J. Hawkins exhibited and remarked upon some specimens of polished Japanese marbles; and Mr. Ogle exhibited specimens of Eocene vertebrate remains, including those of turtle.

ON "LEATHERY TURTLES," RECENT AND FOSSIL, AND THEIR OCCURRENCE IN BRITISH EOCENE DEPOSITS.

BY A. SMITH WOODWARD, F.G.S., of the British Museum (Natural History).

As has often been remarked, there is no order of the Reptilian Class regarding the origin and development of which there is less information than that of the Chelonia. Throughout almost all the Tertiary and Secondary formations their fossil remains are scattered more or less abundantly, but there is very little approach to a generalized type as they are traced back in time, and even so low in the series as the Upper Trias there is undoubted evidence of completely differentiated members of the order. The most obvious character, of course, in which they differ from other reptiles, consists in their possession of a remarkably complete bony armour, adapted—in the dorsal region—to the bones of the axial skeleton; and there is every reason to believe that in this peculiarity the *Chelytherium* of Von Meyer,* from the Upper Keuper Sandstone of Stuttgart, was as distinctively Chelonian as any genus of more modern times.

But it rarely happens that in a group of living organisms there are no surviving relics of an earlier stage of specialization; and, in accordance with the common rule, we find among existing Turtles and Tortoises at least one generic type, which appears to afford some slight glimpse into the condition of the remote ancestors of the group. The "Leathery Turtle" (*Sphargis coriacea*),† inhabiting the more tropical parts of the existing seas, is invested in an armoured covering much less removed from the similar shields of other reptiles than any of its congeners; and a consideration of the general anatomical features of this animal can leave no doubt that it is a direct and little-altered descendant of the most primitive members of the order. As such, it is of peculiar interest to the palæontologist, and the most fragmentary of its remains are worthy of careful study.

Hitherto, however, there is very little fossil evidence of the extinct allies of the genus under consideration; and with the exception of two comparatively perfect Cretaceous fossils, none but small fragments have yet been described. For this reason it may be of some interest to offer a few remarks upon our present knowledge of the important group to which it belongs—especially as so little prominence seems to be given to the type even in the ordinary modern text-books. I also venture to add a brief notice of one other fragmentary fossil, preserved in the British Museum, since its derivation from an English Eocene deposit that has been closely studied by so many members of the Association may not improbably result in the discovery of further remains.

---

* H. von Meyer, "Reptilien aus dem Stubensandstein des oberen Keupers," 'Palæontographica,' Vol. xiv (1865), pp. 120-124, pl. xxix, figs. 2-10. The type specimens are now in the British Museum.

† Duméril and Bibron, 'Erpétologie générale,' Vol. ii, 1835, p. 560, pl. xxiv, fig. 2.—C. J. Temminck and H. Schlegel, 'Siebold's Fauna Japonica —Reptiles,' 1838, pp. 6-12, pls. i-iii.—J. E. Gray, 'Catalogue of the Shield Reptiles in the British Museum,' pt. i, 1855, p. 71.—J. H. Sears, "*Dermatochelys coriacea*, Trunk Back or Leathery Turtle," 'Bull. Essex Institute,' Vol. xviii (1886), pp. 87-94. Mr. Garman admits a second species in his "N. American Reptiles and Batrachians," 'Bull. Essex Institute,' Vol. xvi (1884), p. 6; he also employs the generic name of *Dermatochelys*, which was proposed nine years later than that of *Sphargis* (Agassiz).

As already suggested, it is the relation of the dermal armour to the underlying skeleton that invests the Leathery Turtle with such extreme interest. The dorsal shield (or representative of the "carapace") consists of a large number of irregular, polygonal bony plates, firmly united by jagged sutures, and covered externally by a tough, wrinkled skin; * and the ossifications do not extend to the deepest portion of the integument, so that there is no evidence of them on the under side of the detached shield. A median longitudinal row of these plates, and three pairs of lateral rows, are somewhat larger in size than those adjoining, and are slightly raised, so as to form seven long ridges; while the remaining plates are almost smooth and flat, exhibiting only a small pit in the middle of each, with faint radial grooves.†

There is no connection whatever between this bony dermal armour and the underlying ribs and vertebral spines, such as is the case with the true carapace of more specialized Chelonia, and the only shield bearing any relation to the underlying skeleton is a remarkable squamous plate ‡ attached to the top of the last neck-vertebra, which is evidently represented by the "nuchal" plate in the ordinary turtles and mud-tortoises (*Trionyx*).

The skin of the ventral surface is also studded with numerous small polygonal ossifications, but these are scarcely so compacted together as on the back; § and it is interesting to observe that there are present, in addition, no less than eight of the nine bones which ordinarily form the inferior shield (or "plastron") in Chelonia. These bones, however, are merely represented by overlapping slender splints, and the curious anterior median element, or "entoplastron" (= "interclavicle," Parker), is the portion of which no ossified evidence is observed.‖

---

* In young individuals, scattered horny scutes are also said to be present. Duméril and Bibron, 'Erpétologie générale,' Vol. ii, 1835, p. 559.

† P. Gervais, "Ostéologie du Sphargis Luth (*Sphargis coriacea*)," 'Nouv. Archiv. Mus.,' Vol. viii (1872), pp. 221, 222, pl. ix, figs. 1. 3.—H. G. Seeley, "Note on *Psephophorus polygonus*," 'Quart. Journ. Geol. Soc.,' Vol. xxxvi (1880), p. 409.—St. G. Mivart, Art. "Reptiles," 'Encycl. Brit.,' 9th ed., Vol. xx (1886), p. 447.

‡ P. Gervais, *loc. cit.*, pp. 223, 224, pl. vii, fig. 12.

§ P. Gervais, *loc. cit.*, p. 223, pl. ix, fig. 2.

‖ H. Rathke, 'Ueber die Entwickelung der Schildkröten,' 1848, p. 122; translated in W. K. Parker's 'Monograph on the Shoulder Girdle,' Ray Society, 1868, p. 134.—P. Gervais, *loc. cit.*, pp. 215, 216, pl. vii, fig. 3; pl. viii, fig. 5. The entoplastron is also absent both in the fine skeleton of an adult *Sphargis* and that of a young individual (only four inches long) in the British Museum; and I have failed to discover on what authority this

The skull,* at first sight, bears considerable resemblance to that of the common turtles (*Chelone*), having the same curious roof to the hollow for the biting muscles. But there are several well-marked differences, and one, to be noted in the palate, is especially conspicuous. In front, the vomerine bone is connected merely with the premaxillæ, and there are no palatal outgrowths of the maxillæ, throwing the aperture of the posterior nares slightly backwards, as is the case in the living turtle; and there is no very prominent process from the back of the head, like that of the supra-occipital bone in the more familiar marine type. The frontal bones also differ somewhat, extending forwards almost to the external nostrils, and all the bones are considerably more delicate and scale-like than those of any other existing members of the order.

Notwithstanding the total disconnection of all but one from any superjacent bones, the neural spines of the vertebræ have flattened summits ; † and each arch conforms to the ordinary Chelonian plan in being placed, not directly upon the middle of a centrum, but upon the hinder half of one and the anterior half of the next.‡ The ribs are likewise quite normal—articulating directly (not by transverse processes) with facettes at the junction of each pair of vertebræ—but these bones are remarkable for their very slight expansion.

The limbs and their supporting "arches" are very similar to those of the turtles in general plan, being adapted for analogous conditions of existence ; and, though several features are characteristic, detached bones require comparative study for definite recognition.§

The possession of the more striking of these anatomical characters has caused the remarkable genus in question to assume a con-

---

bone is said to be largely developed in the Leathery Turtles, in the new edition of the 'Encyclopædia Britannica' (Art. 'Reptiles'), Vol. xx, p. 447.

* P. Gervais, *loc. cit.*, pp. 200-208, pl. v, pl. viii, fig. 1. J. E. Gray, "Notes on the Families and Genera of Tortoises (Testudinata), and on the characters afforded by the study of their Skulls," 'Proc. Zool. Soc.,' 1869 p. 224.

† The summits of the neural arches are also flattened to some extent in certain Crocodilia—especially in the heavily-armoured Mesozoic types.

‡ See excellent figure in Art. "Reptiles," 'Encycl. Brit.,' 9th edit., Vol. xx, 1886, p. 449.

§ See figures and descriptions in Gervais' elaborate Memoir already quoted.

tinually more prominent place in the various classificatory schemes of the Chelonia that have successively been proposed. Originally made the type of a family or sub-family by Fitzinger,* Gray,† Strauch,‡ and others, it was first raised to the rank of a sub-order, in 1870, by Professor Cope, § who proposed the name of ATHECÆ in allusion to the imperfection of the external armour, and considered it equivalent to each of two other divisions into which the remaining Chelonia were distributed, according as the hip-bones were united or unconnected with the plastron; the entire order being thus classified as follows :—

I. ATHECÆ. Dorsal exoskeleton not merged with vertebræ and ribs ; plastron very slightly developed. Ex. *Sphargis.*

II. CRYPTODIRA. Carapace and plastron more or less developed : the former always intimately connected with vertebræ and ribs : pelvis disconnected from plastron. Ex. *Chelone*, *Trionyx*, *Emys.*

III. PLEURODIRA. Carapace and plastron well developed : the former always intimately connected with vertebræ and ribs : pelvis connected with plastron. Ex. *Chelys*, *Chelodina.*

Ten years later, Prof. Seeley‖ again proposed a threefold arrangement, regarding the Leathery Turtle as the surviving representative of one section, and dividing the other types into two, according to the absence or presence of horny scutes ; and he further suggested that the granulations upon the dorsal armour of the mud-tortoises *(Trionyx)* might possibly be regarded as definite relics of a dermal shield resembling the tesselated pavement of *Sphargis*, which had become degenerated in these more specialized forms by the progress of evolutional development.¶ The scheme may be briefly stated thus :—

---

* L. Fitzinger, 'Systema Reptilium,' 1843, p. 30.

† J. E. Gray, 'Catalogue of Shield Reptiles in the British Museum,' pt. 1, 1855, p. 71.

‡ A. Strauch, "Chelonologische Studien," 'Mém. Acad. Sci. St. Pétersbourg' [7], Vol. v, No. 7, 1862, p. 58.

§ E. D. Cope, "Catalogue of the Families of the Reptilia," 'Proc. Amer. Assoc. Adv. Sci.,' Vol. xix, 1870, p. 235; "The Reptiles of the American Eocene," 'Amer. Nat.,' 1882, p. 987.

‖ H. G. Seeley, "On *Psephophorus polygonus*," 'Quart. Journ. Geol. Soc.,' Vol. xxxvi (1880), p. 412.

¶ This idea had previously been alluded to by Gervais (*loc. cit.*, p. 224), who considered it disproved by a study of the microscopical structure of the plates.

I. DERMATOCHELYDÆ.* Carapace but slightly developed, and not anchylosed with the vertebræ and ribs in the adult. Ex. Sphargidæ.

II. PELTOCHELYDÆ. Symmetrical bony carapace, more or less firmly united with the vertebræ and ribs in the adult: external surface with granular ornament: no epidermic scutes. Ex. Trionychidæ.

III. ASPIDOCHELYDÆ. Symmetrical bony carapace, firmly united with the vertebræ and ribs in the adult, and covered with symmetrical horny scutes. Ex. Turtles, Emydians, and Tortoises.

Quite recently,† M. Dollo, of Brussels, has advanced a step further, and made the ATHECÆ of equivalent value to all other Chelonia grouped together under the denomination of THECOPHORA; ‡ and there can be little doubt that this arrangement will become universally adopted, as our knowledge in regard to the extinct forms, of which there are already some glimpses, is increased by future discoveries. We agree, however, with a recent reviewer in the 'Geological Magazine,'§ that there is no evidence to suggest that the Chelonian Reptiles had all become toothless by the time that they arrived at this stage of differentiation; and modern researches upon birds || and monotremes afford a strong argument for the non-acceptance of any classification by which the mere presence of teeth in a fossil turtle or tortoise is made to prevent its reference to one or other of the great divisions just mentioned.

Turning to the evidence of fossils, with which we are here more particularly concerned, it is unfortunate that hitherto there have

---

* Prof. Seeley's original definition of this group will not strictly include *Sphargis* itself (the "nuchal plate" being doubtless part of the true carapace), much less Prof. Cope's *Protostega*, which was described before 1880, and Prof. Capellini's *Protosphargis*. We have therefore ventured to make a slight modification above.

† L. Dollo, "Première Note sur les Chéloniens du Bruxellien (Eocène moyen) de la Belgique," 'Bull. Mus. Roy. d'Hist. Nat. Belg.,' Vol. iv, 1886, p. 79.

‡ M. Dollo makes no reference to Prof. Seeley's previous remarks upon the classification of the Chelonia; in this connection, however, it is right to quote the following paragraph from the Professor's earlier paper, *loc. cit.*, p. 412:—"*Sphargis* is the only member known of a great division of the Chelonia which must have included many types of organization, and is probably as important morphologically as all the other Chelonia put together."

§ 'Geol. Mag.' [3], Vol. iii, p. 522 (Nov., 1886).

|| See H. Woodward, Appendix to paper on "Flightless Birds," 'Proc. Geol. Assoc.,' Vol. ix (1886), p. 371.

been no undoubted discoveries of primitive Leathery Turtles in rocks below the Cretaceous. It is true that certain fragments of peculiar dermal shields, more or less suggestive of *Sphargis*, have been described by Von Meyer [*] both from British and from foreign Rhætic beds ; but there is no very good reason for placing these with any type of Chelonian, and Prof. Seeley's more recent researches have led him particularly to express such an opinion [†] in regard to the most perfect fossil—the *Psephoderma alpina.* The latter, however, is quoted by Prof. Cope[‡] as truly belonging to the Chelonian order.

It is also uncertain whether the remarkable tribe of "Macelognatha," discovered by Professor O. C. Marsh[§] in the Jurassic of Wyoming, U.S.A., is to be regarded as allied to the Athecæ, or even to be associated with them ; no remains beyond the dentary bones of the mandible having hitherto been described. But the distinguished Professor of Yale College considers the specimens as very suggestive of a race of toothed Chelonia,[||] and biologists are eagerly looking forward to the discovery of further materials in support of this interesting possibility.

Nor must many other fragmentary fossils of Mesozoic age be referred to the interesting group under consideration without some definite confirmatory evidence ; for it is necessary to remember that in very young Chelonia of the normal type the outer skeleton is much less complete than in the adult condition, and may often lead to the wrong identification of scarcely-hatched individuals when found in a fossil state. Thus we may conclude that the little *Aplax* of Von Meyer,[¶] for example, really owes its imperfect carapace to the accident of immaturity, and not to its appertaining to the Athecan group. Moreover, portions of unornamented, tesselated, dermal armour are not always to be regarded as belonging to animals allied to the living *Sphargis;* for in the British Museum there is the plaster cast of a fossil of this nature, from the Wealden of Sussex, preserved in Mr. Beckles' collection, and there is no doubt whatever that this formed part of a Dinosaurian skin.

---

[*] H. von Meyer, "*Psephoderma alpina*, aus dem Dachsteinkalke der Alpen," 'Palæontographica,' Vol. vi. (1858), pp. 246-252, pl. xxix; and "*Psephoderma anglica*, aus dem Bone-bed in England," *ibid.*, Vol. xv, pp. 261-263, pl. xl, figs. 1-6. See also G. Curioni, 'Mem. R. Instituto Lombardo di Scienze,' Vol. ix, p. 268, pl. vii, fig. 3.

[†] H. G. Seeley, *loc. cit.*, p. 413.

[‡] E. D. Cope, "On the Systematic Arrangement of the Reptilia," 'Proc. Amer. Assoc. Adv. Sci.,' vol. xix (1870), p. 244.

[§] O. C. Marsh, "A New Order of Extinct Jurassic Reptiles (Macelognatha)," 'Amer. Journ. Sci.,' Vol. xxvii (1884), p. 341.

[||] It is worthy of note that in the embryos of certain existing Chelonia there are distinct indications of a toothed ancestry. In *Trionyx*, for example, "the development of the continuous horny maxillary sheath commences from a series of distinct papillæ, which sink into alveolar cavities, regularly arranged along the margins of the upper and lower jaw-bones" (R. Owen, 'Anatomy of Vertebrates,' Vol. i, 1866, p. 385).

[¶] H. von Meyer, 'Reptilien des Lithographischen Schiefers,' p. 129, pl. xviii, fig. 2.

Professor Cope was the first to make known a true fossil Leathery Turtle almost in its entirety, by his discovery of the *Protostega* in the Cretaceous Beds of Western Kansas.* Of this interesting genus he was able to study portions of the cranium, five vertebræ, ten ribs, the pectoral arch, and both humeri, nine phalanges, and a number of dermal bones, all belonging to one and the same individual : and a reference to his beautifully-illustrated monograph will afford a tolerably complete idea of the skeleton of the animal. The bones of the head are even more fragile and scale-like than those of the living *Sphargis*, but they are disposed in an essentially similar manner, and there are no traces of teeth in the jaw. The vertebræ, even in the dorsal region, seem to have been procœlian (concavo-convex), and there are obscure indications of another peculiarity that is equally unknown in the surviving type, namely, the articulation of the ribs with transverse processes at the middle of each vertebra, and not directly with the central at their points of contact one with another. But the ribs are evidently slightly more expanded than those of *Sphargis*, and sometimes exhibit ragged margins, with radiating grooves and ridges upon the upper surface. Of the dermal bones, several are regarded as undoubtedly "marginal" (*i.e.*, as having been arranged round the edge of the back), and a small pit on the under surface of each seems to have lodged the tip of the corresponding rib. Another squamous plate, of symmetrical form, is, perhaps, the representative of the nuchal plate in the existing type; and other larger bony laminæ are considered by Professor Cope as not improbably pertaining to the lateral regions of the upper shield. The entire carapace is estimated to have been about seven feet in length, and seems to have presented a more elongated shape than that of any existing member of the order.

---

* E. D. Cope, "Letter," 'Proc. Amer. Phil. Soc.,' Vol. xii, 1872, p. 175; "A Description of the Genus *Protostega*, a Form of Extinct Testudinata," *ibid.*, pp. 422-423. Also, E. D. Cope, "The Vertebrata of the Cretaceous Formations of the West" ('Rep. U.S. Geol. Surv. Territ.,' 1875), pp. 99-113, pls. ix-xiii.

The discovery of another Athecan genus of Chelonia in the Upper Cretaceous formations of Italy is of great interest on account of the excellent state of preservation of the dorsal vertebræ and ribs, and the bones forming the plastron, or ventral armour, in the single example already described. This fossil, however, exhibits no portions of the skull, and scarcely any traces of the fore-limbs; and the remains of the hinder extremities are likewise not so complete as might be desired. Two years ago, the specimen formed the subject of an elaborate memoir by Professor Capellini,* who proposed the name of *Protosphargis*, in reference to its connection with the progenitors of the existing Leathery Turtle, and added to his description seven beautifully-executed plates. The vertebræ and ribs show none of the aberrant characters supposed to be indicated by the corresponding bones of *Protostega*, and appear to be very similar to those of the living *Sphargis*. There is no evidence of any dorsal dermal plates—though their complete absence in the living animal is, perhaps, not absolutely demonstrated—and the ribs have no ragged, scaly expansions like those of the American genus.† The plastron agrees with that of *Sphargis* in being destitute of an anterior unpaired element (the "interclavicle"), but the two middle pairs of bones ("hyoplastra" and "hypoplastra") are considerably broader than in the existing form, and make a definite approach to the corresponding parts of the ordinary turtles (*Chelone*). It is interesting to observe, also, as Prof. Capellini has pointed out, how closely these plates agree in shape with those of *Protostega*, provisionally referred by Prof. Cope to the lateral regions of the back. It is very probable, indeed, that these "lateral dermal bones" are really hyoplastra and hypoplastra, and that the American form agreed with the Italian in the considerable development of the ventral shield, just alluded to.

According to Professor Cope,‡ there is still other evidence of

---

* G. Capellini, "Il Chelonio Veronese (*Protosphargis veronensis*, Cap.) scoperto nel 1852, nel Cretaceo superiore presso Sant' Anna di Alfaedo in Valpolicella," 'Atti R. Accad. Lincei.' [3], Vol. xviii (1884), pp. 291-320, pls. i-vii.

† It is interesting to note that in the embryos of existing Chelonia the plastron is said to appear before the carapace.

‡ E. D. Cope, 'Proc. Amer. Phil. Soc.,' Vol. xii, 1872, p. 433.

Cretaceous Leathery Turtles in America, though this is certainly very imperfect and fragmentary. Two humeri—or rather one, and half of a second—originally described by Professor Leidy as Mosasaurian, are considered as truly referable to *Protostega*, or some closely-allied form; and one of these, from Columbus, Mississippi, bears the name of *P. tuberosa*,* while the other, from the Greensand of New Jersey, is known as *P. neptunia*.†

Hitherto, no remains of the sub-order appear to have been recognized among British Cretaceous fossils; and I have failed to discover any fragments among the large series of undetermined bones from the Chalk and Greensand in the collection of the British Museum.

Of the Leathery Turtles flourishing in the Eocene Period, no relics have yet been recorded, beyond fragments of the tesselated bony armour. These have been found in the Upper Eocene Limestone of Alabama, U.S.A., associated in such a manner with the bones of the huge primitive whale, *Zeuglodon*, as to lead at first to the idea that they really formed part of the integument of this creature. Carus,‡ indeed, originally figured a specimen showing sixteen tesseræ, as part of the dermal covering of the jaw of *Zeuglodon*; and Müller, again, referred to similar fossils in his work on the last-named genus,§ though here he succeeded in detecting their resemblance to the carapace of *Sphargis (Dermatochelys)*, and suggested that they were truly Chelonian.

Such remains, of course, are of little or no value from an anatomical point of view, and are merely sufficient to indicate the presence of Leathery Turtles in the Eocene seas. In one respect, however, these fragments are far from destitute of interest, namely, as showing that the single existing type is but the degenerate representative of forms which once attained to comparatively huge dimensions.

It is also well worth while to note the occurrence of these isolated fossils in any particular deposit, because they will occasionally afford a clue to the identification of some of the nondescript bones that may be found upon the same horizon. And on this account I propose to call attention to the small fragment in the British Museum, which appears to be the first definite trace of Athecan Chelonia recorded from English Eocene formations.

---

* *Mosasaurus*, J. Leidy, "Cretaceous Reptiles of the United States" (Smithson. Contrib., 1864), p. 42, pl. viii, figs. 1-2.

† *Mosasaurus?* J. Leidy, *op. cit.*, p. 42, pl. viii, figs. 3-5.

‡ C. G. Carus, "Das Kopfskelet des *Zeuglodon hydrarchos*," 'Nova Acta Acad. Cæs. Leop. Carol. Nat. Cur.,' Vol. xxii, 1848, p. 382, pl. xxxix*a*, fig. 5.

§ J. Müller, 'Ueber die fossilen Reste der Zeuglodonten von Nordamerica,' Berlin, 1849, p. 34, pl. xxvii, fig. 7.

The precise locality of the fossil in question is unfortunately uncertain, but Mr. Etheridge is of opinion, from the nature of the matrix, that there can be little doubt of its derivation from the well-known Middle Eocene strata of Bracklesham, in Sussex. It must originally have belonged to an animal quite as large as the Alabama specimens already mentioned. The thickness of the fragment varies from seven to eleven millimetres, and it exhibits six tesseræ of unequal size and irregular shape. The largest of these divisions is at the thickest end, oblong, and measuring approximately six-and-a-half centimetres by three-and-a-half; while the smallest is of a nearly quadrate form, and is scarcely more than two centimetres across. All the sutures are distinctly visible on the inferior surface of the shield, as well as on the upper; and there are some indications of these having been jagged, as in the existing *Sphargis*, though it would require a section to show the character satisfactorily. The bone is very dense, the superficial layer being especially so, and the deeper parts exhibiting a more cancellous structure; and the external surface is almost smooth, showing only one or two small indented pits towards the centre of each tessera.

Fossils very similar to that just described, and of equally large size, have been made known by Gervais,* from the Miocene beds of Vendargues, Hérault, France, under the name of *Sphargis pseudostracion*. There is, however, no proof of their appertaining to the existing genus, nor do such specimens admit of any specific diagnosis; so that it seems advisable to await the discovery of further materials before definitely naming the British form. The first of Gervais' figured specimens was originally described as part of the dermal skeleton of a "Coffer-fish" allied to *Ostracion*, and the second shows a trace of one of the carinate ridges so characteristic of the *Sphargidæ*.

The most complete remains, however, of an early Tertiary Leathery Turtle hitherto recorded were unfortunately fossilized by iron pyrites; and nearly the whole skeleton was dispatched to a chemical works, where the precious relics were rapidly utilized in the manufacture of sulphuric acid. This interesting discovery was made in the Oligocene (Rupelian) strata of Waas, in Belgium, and only eight fragments were preserved for the study of the biologist. Prof. Van Beneden has published an interesting notice * of the relics, which comprise three dermal plates, three vertebræ, a coracoid, and an ilium; and he has shown that they closely correspond with the homologous bones of the living *Sphargis.* They are too imperfect, however, for precise specific determination, though the author ventures to give them the provisional name of *S. rupeliensis.* The dermal plates are described as possessing a well-marked superficial ornament; and it is interesting to note that this animal agreed with all its known congeners of early Tertiary date in its comparatively large dimensions.

---

* P. Gervais, 'Zoologie et Paléontologie françaises,' 2nd. Edit., 1859, p. 438, pl. ix, fig. 1; and "Ostéologie du Sphargis," 'Nouv. Archiv. Mus.,' Vol. viii, 1872, p. 222, pl. ix, fig. 4.

As an important fossil Leathery Turtle of still more recent times, the *Psephophorus polygonus* of Von Meyer remains to be mentioned. This form is known from an interesting slab from the Pliocene of Neudörfl, on the borders of Austria and Hungary, preserved in the Geological Museum of Vienna; and it was first exhaustively studied by Professor Seeley, who published an elaborate description of its characters in 1880.† The fossil in question comprises part of a tesselated shield, which shows a short length of one of the longitudinal, keel-like ridges so characteristic of *Sphargis;* and there are also preserved some more or less fragmentary remains of five vertebræ. The dermal plates—except those of the ridge—are slightly ornamented on the external surface with radial markings; and, except in size, it is difficult to distinguish the shield from that of the surviving type. Professor Seeley suspects, however, that the number of longitudinal keels may have been less than seven. It is interesting to note, further, that there is some evidence of a less complete inferior armour, quite similar to that of the surviving type.‡ The complete distinctness of the Pliocene fossil is demonstrated, however, by the few remaining vertebræ, which seem to belong to the posterior cervical or dorsal region. There are well-marked transverse processes, anchylosed to the centrum, such as have already been mentioned in connection with the Cretaceous *Protostega;* and "the great development and height of the neural arch" are, likewise, quite extraordinary.

---

* P. J. van Beneden "Note sur les ossements de *Sphargis* trouvés dans la terre à brique du pays de Waas," 'Bull. Acad. Belg.' [3], Vol. vi, 1883, p. 665, plate.

† H. G. Seeley, "Note on *Psephophorus polygonus*, v. Meyer, a new Type of Chelonian Reptile allied to the Leathery Turtle," 'Quart. Journ. Geol. Soc.,' Vol. xxxvi (1880), pp. 406-413, pl. xv. References to previous notices of the fossil are here given.

‡ Prof. Seeley was evidently unacquainted with Gervais' memoir on *Sphargis* already quoted. He remarks that tesselated bony plates are absent upon the ventral aspect in the existing genus.

With the Austrian Pliocene fossil, the palæontological history of the Leathery Turtles, for the present, ends. It is obviously a most imperfect and fragmentary record, and such as it is frequently the lot of the student of past life to be compelled to accept with contentment. It may even be suggested that the various scattered allusions to the subject have proved scarcely worthy of collation. But the task has not been altogether in vain, if the foregoing array of facts tends in any measure to emphasize the morphological importance of the group of Leathery Turtles, which have rarely been given sufficient prominence in any but technical memoirs; and the series of bibliographical references may possibly be of some slight service to the next fortunate discoverer of fossils of this character, in the all-important preliminary search through the writings of his predecessors.

ON SOME FURTHER RESEARCHES IN BONE-CAVES IN NORTH WALES.

BY HENRY HICKS, M.D., F.R.S., F.G.S.

Since I read my paper 'On some Recent Researches in Bone-Caves in Wales,' before the Association, on Nov. 7th, 1884, I have, in conjunction with others, carried on some further explorations in the Ffynnon Beuno and Cae Gwyn Caverns, which were described for the first time in that paper. The results obtained have been given in papers to the Geological Society* and to the British Association for the Advancement of Science.† The caverns have been worked by the aid of grants from the Royal Society and from the British Association.

They are situated in a Carboniferous Limestone escarpment, forming the north side of a ravine near Tremeirchion, on the east side of the Vale of Clwyd, and are about two miles from the

---

* 'Quart. Journ. Geol. Soc.,' Feb., 1886.

† 'Brit. Assoc. Reports,' 1885 and 1886.

Bodfari Station, on the Chester, Mold, and Denbigh Railway. The heights of the caverns above sea level are about 380 and 400 feet respectively, and they are about 42 and 62 feet above the stream in the ravine.* The ravine was evidently excavated in pre-glacial times, but was afterwards filled up during the Glacial period with sands, gravels, and boulder-clay. Since then these deposits have been gradually removed by subaërial denudation, but the stream has not as yet reached the original floor of the valley. At different points along the valley, the boulder-clay, with its associated sands and gravels, is left in miniature terraces at various heights, some being above the horizon of the caverns. Fragments of shells occur in the sands and gravels, usually in too imperfect a condition for determination. Ice-scratched boulders, many of large size, one Arenig boulder being several feet in diameter, may be seen on the hill-side to the east of the caverns, and are very plentiful wherever sections have been made in the clay. The majority of the boulders are of local origin, but there are felstones and other rocks from the Snowdonian and Arenig areas, and granitic and gneissic rocks from northern sources. Attempts have been made to sub-divide the glacial deposits of this area, but Mr. Strahan, of the Geological Survey, in his recently-published memoir on the geology of this area, says† "that no detailed classification applicable to the whole area" has been found possible, and that "the passage from the one boulder clay into the other is gradual, nor can it be said that one under or over-lies the other. They were, no doubt, formed contemporaneously, differing only in the source of supply of material."

The Ffynnon Beuno Cavern is partly a fissure and partly a tunnel-cavern. From the entrance inwards for a distance of about 40 feet it is a true tunnel-cavern, and there is a branch tunnel extending from this for a further distance of over fifty feet, ultimately opening out on the hill-side above the main entrance. Another tunnel communicates with an extensive fissure cavern, which had evidently been disturbed at some time by mining operations (though I could obtain no information as to when). In the undisturbed part of the cavern, at a distance of about 20 feet from the entrance, the following deposits were recognized: 1. Surface soil. 2. Stalagmitic breccia with some charcoal. 3. Reddish cave earth with bones of Pleistocene animals, and a flint implement. 4. Gravel consisting mainly of local materials with angular blocks of limestone. There was an open space at this point, above the deposits, of from five to seven feet. This being for some extent an open cavern, had probably been inhabited also in Neolithic or perhaps later times. The material below the stalagmitic breccia, it was clear, however, had not been disturbed since Pleistocene times, and the flint implement and the bones must be classed as of that age. Several other flint implements were found at different points in this cavern in association with bones of the mammoth, rhinoceros, &c. Worked bones and others apparently broken by man were also found. The bones were exceedingly plentiful in the cavern, and showed indications of having been freely gnawed, evidently when in a fresh condition, hence proving clearly that they had been conveyed into the cavern soon after the animals had died. Some *album græcum* was also found, therefore the evidence points conclusively to its having been a den occupied by beasts of prey. The materials found in the inner tunnels, which were completely blocked up, must have been rearranged in Pleistocene time by water-action, as a considerable amount of a sandy material occurred there distributed throughout. It is perfectly certain that these deposits had not been disturbed by man, and the evidence obtained seems to point unmistakeably to the conclusion that the bones, which occurred plentifully in them from the base to the roof, must have been carried there from some other part of the cavern by water-action; or that a rearrangement of the materials previously in these tunnels had taken place by water-action, and at the same time that sands and gravels like those to be seen at this horizon in the valley at present, were forced in through the mouth of the cavern to be mixed up with the cave-earth and bones.

---

* In my former paper, by mistake, the height of the Ffynnon Beuno Cavern above sea-level is given at 280 feet.

† 'The Geology of the Coasts adjoining Rhyl, Abergele, and Colwyn,' pp. 28 and 31.

In the Cae Gwyn Cavern all the deposits were, when we commenced our explorations, entirely undisturbed, except by burrowing animals. The deposits, in descending order, may be described generally as consisting, first, of a reddish clayey earth, varying in depth from two to four feet; below this, a more compact deposit, about 18 inches in thickness, made up of thin layers of fine marly clay; and, under this, the material containing the bones. This material consisted of a reddish clay with sand in places, and contained a few small boulders similar to some of those found in the boulder-clays of the district. Large fragments of a stalagmite floor and of stalactites occurred also in it, showing that the water-action which disturbed the original materials had also broken up the thick stalagmite floor in the cave, and therefore that it must have been of a violent nature. Under this was found a gravelly deposit, containing fragments, mainly from the hills above, and no bones. All the deposits in the main tunnel of this cavern, except the lowest, have now been cleared out, and another entrance has been reached, which was completely buried under some glacial deposits. It was found necessary to dig a shaft through these deposits, from the field above, in front of the entrance, and by this means an excellent section, 20 feet in depth, was exposed. The upper part of the section was made up of a tolerably stiff boulder-clay containing many ice-scratched boulders and narrow bands and pockets of sand. Below this there were about seven feet of gravel and sand, with here and there bands of red clay, having also many ice-scratched boulders. The next deposit met with was a laminated brown clay, and under this was found the bone-earth, a brown, sandy clay, with small pebbles, and with angular fragments of limestone, stalagmite, and stalactites. On June 28 of this year (1886), in the presence of Mr. G. H. Morton, F.G.S., of Liverpool, and myself, a small but well-worked flint-flake was dug up, by one of the workmen, from the bone-earth on the south side of the entrance. Its position was about 18 inches below the lowest bed of sand. Several teeth of hyæna and reindeer, as well as fragments of bone, were also found at the same place, and at other points in the shaft teeth of rhinoceros and a fragment of a mammoth's tooth. One rhinoceros tooth was found at the extreme point examined, about six feet beyond, and directly in front of, the entrance. It seems clear that the contents of the cavern must have been washed out by marine action during the great submergence towards the close of the Glacial period, and that they were afterwards covered by marine sands and by an upper boulder-clay, identical in character with that found at many points in the Vale of Clwyd and in other places on the North Wales coast. The glacial deposits here are undoubtedly in an entirely undisturbed condition, and are full of smooth and well-scratched boulders, many of them being of considerable size. The animal remains found in these caverns, as identified by Mr. W.

Davies, F.G.S., of the British Museum, comprise teeth of eleven genera and sixteen species, viz.:—Lion, wild cat, spotted hyæna, wolf, fox, bear, badger, wild boar, bovine, great Irish deer, red deer, roebuck, reindeer, horse, woolly rhinoceros, and mammoth.

The palæontological evidence shows that these caverns, like most other Pleistocene caverns, contained many of the animals found in the Norfolk forest-bed, admitted by all to be of pre-glacial age. The absence of other forms may only show that they had probably not migrated into this area, hence this cannot be relied upon as evidence of important difference in age. I am perfectly convinced by the evidence found during the exploration of these caverns that they must have been occupied by man and the animals, before the climax of the Ice age; also that the thick stalagmite was formed some time during that age; that this was broken up by marine action during the submergence; and that the caverns were afterwards completely covered over by materials deposited from floating ice. There seems, therefore, to be every reason to suppose that man and the so-called Pleistocene animals arrived in this country in advance of the Glacial conditions, and that their migrations were mainly from northern and north-western directions.

ORDINARY MEETING.

Friday, January 7th, 1887.

W. Topley, Esq., F.G.S., Assoc.Inst.C.E., President, in the Chair.

The donations to the library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected members of the Association:—H. W. Burrows; F. Chapman; C. Fox; C. R. Griffiths; J. N. Johnston; J. H. Leonard; E. Locke; Rev. W. Spiers, M.A., F.G.S.; and Rev. R. S. Tabor, M.A.

Mr. H. H. French and Mr. S. H. Needham were elected Auditors for the past year's accounts.

The following lecture was then delivered:—'On Crinoids and Blastoids.' By Dr. P. H. Carpenter, F.R.S.

The lecture was illustrated by slides, exhibited with the sciopticon, by Mr. Wm. Lant Carpenter, B.A., B.Sc.

ON CRINOIDS AND BLASTOIDS.*

BY P. HERBERT CARPENTER, D.Sc., F.R.S., F.L.S.

The term *Crinoidea* was first used by Mr. J. S. Miller, a naturalized German resident in Bristol. In the year 1821 he published a work entitled 'A Natural History of the Crinoidea,' in which he introduced the name to designate certain animals resembling lilies in their general shape (κρίνον, a lily). The recent species upon which his studies were largely based was the well-known form which he called *Pentacrinus Caput-Medusæ* (= *Isis asteria*, L.), a creature found in deep water in the West Indies, which, both at that time and for long afterwards, was extremely rare. Our knowledge of the soft parts of the Crinoids has been vastly extended since Miller's time, owing to the large number of forms brought to light in recent years by deep-sea exploration. Miller's researches were also directed to various fossil forms, and he established several of the best known genera among the Palæozoic Crinoids, *e.g.*, *Actinocrinus*, *Cyathocrinus*, and *Platycrinus*. These, and others of Miller's genera, have since been more precisely defined, and his names, as he understood them, represent the "families" of modern palæontology.

In Miller's day the Crinoids, like the Sea-Urchins, were regarded as forming a zoological "family;" but this term then bore a higher meaning than it conveys at the present time. The Crinoids are now said to form a "class," belonging to the sub-kingdom of the *Echinodermata*. This group is one of the great sub-divisions of the animal kingdom, and also includes the sea-urchins, star-fishes, brittle-stars, and holothurians, with various extinct stalked forms more or less closely resembling the Crinoids.

As far back as the year 1848 Leuckart proposed the term *Pelmatozoa* (πέλμα, a stalk) for those Echinoderms which are fixed, either permanently or temporarily, by means of a stalk. The term, after having fallen into disuse, has been recently revived as a convenient designation for a primary group of Echinoderms. As it includes all the stalked types, it embraces not only the Crinoids, skeleton, and stand up as five triangular valves around the mouth, every two of them being separated by an ambulacral groove, which extends on to the growing arm.

---

* The substance of an address (illustrated by several photographs shown by the Sciopticon) from notes taken by F. W. Rudler, Esq., F.G.S., and revised by the lecturer.

The stem of a *Pentacrinus* is composed of a number of more or less pentagonal joints, some of which bear whorls of *cirri,* like those on the top stem-joint of *Comatula*, and are, therefore, known as *nodal joints*, while the others are distinguished as *internodal joints.* The inferior surface of each nodal-joint is attached to the top joint of the internode below (*infra-nodal*) by that mode of union which is known as a *syzygy*. This term was introduced by Johannes Müller, to indicate an immovable sutural union between the arm-joints, but was also applied by Sir Wyville Thomson to a similar union between two stem-joints. The stem of *Pentacrinus* is more readily broken across at a syzygial union than at any other part. If a living *Pentacrinus* happens, when swimming, to catch its stem in any object, it can easily snap it off at a syzygy, and anchor itself by means of the cirri on the lowest remaining nodal joint. Fossil stems of the *Pentacrinidæ* are often found in fragments, naturally severed along the lines of the syzygies ; and one end, or both, of each fragment then exhibits the smooth syzygial face.

At the summit of the stem of *Pentacrinus* are five basal plates (b),* which are interradial in position, and rest on the angles of the upper stem-joints. In some species they form a closed ring at the base of the calyx ; but in a few Crinoids, as in most *Comatulæ,* no basals are visible on the exterior of the calyx. In some of the Palæozoic Crinoids (*e.g.*, *Cyathocrinus*), and in a few Mesozoic species (*e.g.*, *Encrinus*), the basals are separated from the uppermost stem-joint by a ring of radially situated plates, the *under-basals* (u). Above, and alternating with, the five basals of *Pentacrinus,* are five radials, forming a closed ring. These, which are the primary or first radials (r^1), are succeeded in turn by a row of second radials (r^2), and these by the third, or axillary radials (ra). Each of the latter bears two arms, which may either remain single or divide more or less frequently. In the latter case the joints up to, and including, the next axillary (da) are termed *distichals.* The distichals are thus the joints of the primary arms, which may divide and subdivide until the total number of arms becomes very considerable. For purposes of description the joints of the secondary arms are conveniently distinguished as *palmars*, while the joints above the last axillary are the *brachials.*

---

* See the diagram on p. 27.

The genus *Pentacrinus* was established by Miller, who recognized five species. Of these the only recent species was the West Indian *P. Caput-Medusæ*, originally described by Linnæus as *Isis asteria*. Of late years the old specific name has been revived in place of Lamarck's *Caput-Medusæ*, and hence the species is now properly known as *Pentacrinus asterius*.

Some interesting new species of *Pentacrinus* have been obtained by recent deep-sea exploration. The name *Pentacrinus Wyville-Thomsoni* was given by the late Dr. Gwyn Jeffreys to a Crinoid first obtained by the "Porcupine" in 1870, at a depth of 1,095 fathoms off the coast of Portugal, and since dredged at a smaller depth by a French expedition. In this species, short, stout cirri occur at regular and rather long intervals along the stem, which, in many cases, was in a semi-free condition, having been broken at a syzygy in the manner already described.

An elegant species, dredged by the "Challenger," at a depth of 350 fathoms, off Pernambuco, on the coast of South America, is represented at present by only a single specimen. It was named by Sir Wyville Thomson *Pentacrinus maclearanus*, and is of interest to geologists, inasmuch as it presents certain characters recalling the Liassic *Extracrinus briareus*. The stem is pentagonal, with rounded angles; the nodal joints are closely approximated; each ray generally bears six arms, and the cirri have a slight downward curvature.

Miller was acquainted with two Liassic species of *Pentacrinus*, namely, *P. briareus* and *P. subangularis*. These forms were transferred by Messrs. Austin to their genus *Extracrinus*. In *E. briareus* the stem is not especially long, but in *E. subangularis* it may exceed 50 or even 70 feet in length. *E. briareus* has the nodal joints closely approximated, and is provided with a great number of subsidiary arms, or armlets, branching off from the inner sides of the principal arm-trunks. Enormous colonies of *Extracrinus* must have flourished on the floors of the Liassic seas; but although most numerous in the Lower Lias, its remains are also found in Britain in the Great Oolite, Forest Marble, and Cornbrash.

The *Apiocrinidæ*, or Pear Encrinites, are characterized by the absence of cirrus-whorls on the stem. There may be a few radicular cirri, but there is no division of the stem-joints into nodal and internodal. The summit of the column expands, and there are five large basal plates at the bottom of the calyx. In most members of the group the number of arms is ten, as in the well-known Pear Encrinite of the Bradford Clay (*Apiocrinus Parkinsoni*), but this number may sometimes be exceeded.

The *Apiocrinidæ* of the Oolitic seas are represented in the Chalk by the *Bourgueticrinidæ*, a group comprising smaller and apparently degenerate types. The genus *Bourgueticrinus* seems to be confined to Cretaceous rocks;* for the stem-joints from Eocene deposits, which have been referred to this genus, are in all likelihood those of the still more degenerate *Rhizocrinus*, which is found in various parts of the Atlantic, and is the modern representative of the Secondary *Bourgueticrinidæ* and *Apiocrinidæ*. The genus *Rhizocrinus* was established by the late Michael Sars, in 1864, for the reception of a new Crinoid dredged off the Lofoten Islands by Prof. G. O. Sars. Special interest attaches to this Crinoid, since it may be regarded as representing the starting point of recent British deep-sea exploration, inasmuch as it was mainly due to the interest of Sars's discovery that the late Dr. W. B. Carpenter and Sir Wyville Thomson were led to take action in the matter, and to secure official aid for the cruises of the "Lightning" (1868) and the "Porcupine" (1869-70), which ultimately led to the expedition of the "Challenger." In *Rhizocrinus*, and in the allied genus *Bathycrinus*, the joints of the stem are of dice-box shape; and there may be a number of radicular cirri, branching irregularly from its base. The calyx of *Rhizocrinus* is composed of five long basals and five radials, which bear single arms. The arm-joints are united in pairs by syzygies, and the pinnules are limited to the upper or "epizygal" joint of each pair.†

The deepest dredging (2,435 fathoms) of the "Porcupine" in the Bay of Biscay in 1869 yielded a small Crinoid, to which Sir Wyville Thomson gave the name of *Bathycrinus*. The work of the "Challenger" brought to light larger specimens of new species of the same genus, all obtained from deep water. *Bathycrinus* stands close to *Rhizocrinus* in its structural relations, but has smaller basals, and ten arms instead of five only; but it has not yet been discovered in the fossil state.

The remarkable genus *Holopus* was first described by D'Orbigny as far back as 1837. His specimen, obtained from Martinique, was for a long time unique, and was notable for having only four rays instead of five, as in most Crinoids. Sir Rawson Rawson, when Governor of Barbadoes, obtained some specimens which were normally pentamerous; and other examples of the type have since been dredged in the Caribbean Sea. The basals and radials are fused together into a tubular calyx, which is fixed to the sea-bottom by an expanded base. There are ten massive arms closely curled inwards over the disc, which is chiefly occupied by five large oral plates. *Holopus* shows affinities with many ancient types. It is clearly related to the fossil form from the Faxoe Chalk, described by Steenstrup in 1847 as *Cyathidium*. Close relationship may also be traced with the Liassic genus *Cotylecrinus*, and with the Palæozoic *Edriocrinus*, described by James Hall, from the Upper Silurian rocks of New York, all these genera being sessile, and unprovided with a stem.

---

* *Bourgueticrinus ooliticus*, McCoy, may perhaps be a *Thiolliericrinus*.

† The lower or "hypozygal" joint (h) of a syzygial pair never bears a pinnule.

Marsupites, the well-known "Tortoise Encrinite" of the Chalk, is a curious type of apparently sessile Crinoid, with large under-basals. In *Agassizocrinus*, an American Palæozoic Crinoid, we possibly have the forerunner of *Marsupites*. It was probably a free form, like *Comatula*, with its under-basals anchylosed into a solid piece, closing the bottom of the cup.

Fossil *Comatulæ* occur in the Jurassic, Cretaceous, and Tertiary formations. The genera *Antedon* and *Actinometra* are found in the Lias of France, but are not known in this country from rocks older than the Inferior Oolite. In *Antedon* the mouth is central; in *Actinometra*, excentric, as already described.

The genus *Woodocrinus*, named after the late Edward Wood, of Richmond, in Yorkshire, is characteristic of the Carboniferous Limestone of Richmond. In this genus the basals are separated from the stem by a ring of under-basals (u), which were called basals by Johannes Müller; while he gave the name "parabasals" to the true basals (b) which lie immediately beneath, and alternate with the radials, and were termed "sub-radials" by de Koninck. *Woodocrinus* has about twenty rather massive arms, and the lower part of the stem tapers towards the base; so that this Crinoid would seem to have been partially or entirely free, and not fixed, as is usually the case.

The *Blastoidea* constitute a peculiar group of stalked but armless Echinoderms which were separated from the brachiate forms, or *Crinoidea* proper, in 1825, by Thomas Say, of Philadelphia; but

a. Higher anal plates.
id. Interdistichals.
p. Pinnule.
s. Syzygy. h, hypozygal. e, epizygal.
b.a. Biserial arm.
u.a. Uniserial arm.

The figures 1, 2, 3, are placed in the angle of each pair of primary, secondary, and tertiary arms, respectively.

The Basals and First Radials correspond to the Genital and Ocular Plates of an Urchin. All the plates which are above the First Radials, and lie in the direction of the rays, are in reality arm-joints; but the various series between the successive axillaries are called radial, distichal, palmar, &c., for convenience in description. They are sometimes spoken of as the various orders of radials.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 4TH, 1887.

W. TOPLEY, ESQ., F.G.S., Assoc.Inst.C.E., President, in the Chair.

The Minutes of the previous Annual Meeting having been read and confirmed, Mr. J. Fox and Mr. T. Leighton were appointed scrutineers of the ballot for the new Officers and Council.

The following Report of the Council for the year 1886 was then read :—

In spite of the prevailing commercial depression, which threatened to make its influence felt by causing a thinning of our ranks, and which probably did cause the greater number of the removals from our list, the census of the Association shows a slight increase of strength, and on December 31st was as follows:—

Honorary Members	15
Ordinary Members :—	
a Life Members (Compounded)	114
b Old Country Members (5s. Annual Subscription)	14
c Other Members (10s. Annual Subscription) ...	353
Total	496

During the year 73 new members were elected. The Council regret that the Association has lost five members by death :—Mr. George D. Brown, Mr. Caleb Evans, Mr. P. W. Freeland, Mr. E. W. Godwin, and Professor J. Morris, whose "Life" formed the theme of our President's address at the last Annual General Meeting.

In Mr. Caleb Evans, F.G.S., who died September 16th, 1886, at the comparatively early age of 55, the Association loses one of its first members and truest friends. Mr. Evans began to study geology in 1855, was elected a member of this Association in 1859, and a Fellow of the Geological Society in 1867. His attention was mainly directed to the study of the English Tertiaries and the Chalk, and from 1858 his official vacations were spent in visiting various localities of geological interest, and in forming what at the time of his death had become a most valuable collection. Many of the specimens are from sections now inaccessible, such, for example, as drainage and other works, both in the north and south of London. One of those quiet, enthusiastic workers, who write but little, that little, however, being thorough, his published papers are not numerous, and with one or two exceptions appear in the pages of our 'Proceedings.' Of these, the best known and most important are:—'On the Geology of the Neighbourhood of Portsmouth and Ryde' (*Proc. Geol. Assoc.*, ii, 61-76, and 149-74); 'On the Geology of Hampstead' (*ib.*, iii, 21-32); 'On the forms of the genus *Micraster* common in the Chalk of West Kent and East Surrey' (*ib.*, v, p. 149-54 : 1 pl.). His name, however, will be for ever associated with that detailed and carefully worked-out memoir, 'On some Sections of Chalk between Croydon and Oxtead,' which was read before the Association in 1870, and appeared as a separate publication. In this paper is recorded the first attempt made in our country to sub-divide the Chalk into zones according to the fossil contents, and to correlate these divisions with corresponding beds in other parts of these islands, and on the neighbouring portions of the Continent. Mr. Evans conducted four excursions of the Association: to Sevenoaks, on Easter Tuesday, 1874; to Riddlesdown and Croydon, in April, 1875; and two to Hampstead, in June, 1874 and 1876. None of these will be forgotten by those who had the good fortune to be present. As an instance of the persevering energy of the man may be cited a model in relief, done to scale, of the district around Hampstead, constructed entirely from observations which he himself had taken, and made with his own hands out of innumerable pieces of cardboard. This was exhibited at one of the evening meetings. Other similar geological relief maps were also constructed by Mr. Evans, viz.:—The Thames Valley in the neighbourhood of London; the country around Hastings; the vicinity of Sidmouth; and one of England and Wales.

In the last report attention was called to the fact that while the expenditure of the Association was rapidly augmenting, there was not a corresponding increase in the receipts. The growth of the expenditure was shown to be due to exceptional causes, which it was anticipated would not continue to prevail. This expectation, however, has not been realized, for in no previous year, owing to the many valuable papers which have been communicated, have the

'Proceedings' been nearly so voluminous. The receipts, on the other hand, have been greater than in any preceding year, a result due to the large accession of new members, and to the number who have compounded. Your Council recommends the investment of the sum of £10 in Consols, which will make the funded property of the Association cover the composition fees of its known Life Members.

Since the last annual meeting four numbers of the 'Proceedings' have been issued, viz., Nos. 4-7, inclusive, of Vol. ix, comprising, in all, 356 pages, illustrated with nine plates, a map, and 76 cuts. We are indebted to Dr. Henry Woodward, Mr. J. Starkie Gardner, Mr. J. G. Goodchild, and Professor T. Rupert Jones, for the gift of the plates and some of the woodcuts illustrating their respective communications. The year has been exceptionally rich in palæontological publications, including papers on Crocodiles, Birds, Trilobites, Ostracods, and Grasses.

The very general and constant use of the books contained in the Library has been well maintained during the past year. Your thanks are due to Mr. Herbert Taylor, who after kindly acting for some years as Assistant-Librarian, is now, owing to pressure of other duties, obliged to retire; but the members will be glad to learn that his place will be taken by Mr. E. Litchfield, who retires from the Council for the express purpose of again placing his services at their disposal.

The following is a list of the papers read at the evening meetings:—

'Considerations on some phenomena observed in the Devonian and Carboniferous Rocks of Belgium,' by M. ED. DUPONT, Director of the Royal Museum, Brussels; of the Geological Survey of Belgium. Translated from the French by Miss MARY FORSTER.

'Supplementary Note to his Paper on Wingless Birds,' by Dr. HENRY WOODWARD, F.R.S., Keeper of Geology at the British Museum.

'Note on the Large Bird from the Eocene of Croydon, found by H. M. Klaassen, F.G.S.,' by E. T. NEWTON, F.G.S., of the Geological Survey.

'The Life and Work of Prof. John Morris,' by W. TOPLEY, F.G.S., &c.

'On the Stratigraphical relations of the Bagshot Sands of the London Basin to the London Clay,' by the Rev. A. IRVING, B.A., B.Sc., F.G.S.

'On the Fragmentary Ejectamenta of Volcanoes,' by H. J. JOHNSTON-LAVIS, M.D., F.G.S., &c.

'On Grasses,' by J. STARKIE GARDNER, F.L.S., F.G.S.

'On some Trilobites from the Skiddaw Slates,' by J. POSTLETHWAITE, F.G.S., &c., and J. G. GOODCHILD, F.G.S., F.Z.S., &c., of H.M. Geol. Survey.

'On the Connection in time of changes in Fossil Floras with those of Faunas,' by Prof. G. S. BOULGER, F.L.S., F.G.S.

'A List of the Genera and Species of the Entomostraca found in the Carboniferous Formations of Great Britain and Ireland, with Notes on the characters 'and distribution of the Genera,' by Prof. T. RUPERT JONES, F.R.S., and J. W. KIRKBY.

'Sketch of the Geology of Northumberland,' by Prof. G. A. LEBOUR, M.A., F.G.S.

'Petrographical Notes on the Igneous Rocks of Northumberland,' by J. J. H. TEALL, M.A., F.G.S.

'On the Erosion of the Coasts of England and Wales,' by W. TOPLEY, F.G.S., &c.

'On Fossil Leathery Turtles and their Occurrence in British Eocene Deposits,' by A. SMITH WOODWARD, F.G.S., Assistant in the Geological Department, British Museum (Natural History).

'On some Further Researches in Bone Caves in Wales,' by Dr. HENRY HICKS, F.R.S., &c.

During the past year the quondam practice of exhibiting specimens at the evening meetings has been revived with great success, and it is hoped that the custom may both continue and increase, as it greatly enhances the interest of the meetings, which have been uniformly well attended.

Subjoined is a list of the Museums and geological collections visited during 1886, and your Council would here especially refer to the series of Conferences held in the Colonial and Indian Exhibition, at which very valuable addresses were delivered on the geology of our Colonies, more especially in relation to their mineral resources, by the most competent authorities.

These conferences were well attended, and we have to thank the Commissioners of the Exhibition for their generous presentation of a number of free tickets.

Science Schools, South Kensington, on March 30th, when Prof. Judd, F.R.S., conducted the members over the building, and explained its general arrangement, and the methods of study adopted there.

South Kensington Museum, on April 10th, when Prof. Judd, F.R.S., conducted the members over the Science Collection, and gave a Demonstration on some of the apparatus.

Museum of the Royal College of Surgeons, Lincoln's-Inn-Fields, on April 17th, when a Demonstration on *Pterosauria*, &c., was given by Prof. Charles Stewart, F.L.S., Curator of the Museum.

Blackmore Museum, Salisbury, on April 26th, when Dr. Blackmore gave a Demonstration on the remarkably fine collection of Implements and Mammalian Remains from the Gravels of that neighbourhood, as well as on the extensive collection of Implements, both prehistoric and those of modern savages, from all parts of the world.

Colonial and Indian Exhibition, South Kensington, on June 5th, when, under the presidency of Sir Richard Temple, Bart., G.C.S.I., M.P., an Address was delivered on 'The Mineral Resources of India and Burmah,' by Professor V. Ball, M.A., F.R.S., followed by a Demonstration of the specimens exhibited in the Indian Courts.

Colonial and Indian Exhibition, South Kensington, on June 19th, when, under the presidency of Sir Charles Mills, K.C.M.G., an Address was delivered on 'The Mineral Resources of South Africa,' by Professor T. Rupert Jones, F.R.S., followed by a Demonstration of the exhibits in the South African Courts, including numerous examples of Diamonds, large Models of Diamond Mines at Kimberley, and examples of Diamond-washing Machinery, which were shown in action by Messrs. Ford and Wright, of Clerkenwell, who also explained the processes by which diamonds are cut and polished.

Museum of Dr. Brett, at Watford, on June 26th.

Colonial and Indian Exhibition, South Kensington, on July 3rd, when, under the presidency of the Rt. Hon. the Marquis of Lorne, K.T., an Address was delivered on 'The Mineral Resources of Canada,' by A. R. Selwyn, C.M.G., LL.D., F.R.S., followed by a Demonstration of the exhibits in the Canadian Court.

Maidstone Museum, on July 10th, when the local collections of Cretaceous and Pleistocene Fossils and of Flint Implements were inspected.

Colonial and Indian Exhibition, South Kensington, on July 17th, when, under the presidency of Sir F. Dillon Bell, C.B., K.C.M.G., an Address was delivered on 'The Mineral Resources of New Zealand,' by Sir Julius Von Haast, K.C.M.G., F.R.S., followed by a Demonstration of the exhibits in the New Zealand Court.

Colonial and Indian Exhibition, South Kensington, on July 24th, when the President of the Association took the chair; an Address was delivered on 'The Mineral Resources of Australia,' by F. W. Rudler, F.G.S., followed by a Demonstration of the exhibits in the Australian Courts.

Museum of the Natural History Society of Northumberland, on August 3rd, when those who took part in the Long Excursion were conducted over the building by the Curator, Mr. R. Howse.

The following is a list of the Excursions made during the past year, detailed reports of which will be found in the number of the 'Proceedings' for November, 1886 :—

To Salisbury and Stonehenge, on Easter Monday and Tuesday, April 26th and 27th, in association with the Hampshire Field Club, under the direction of Dr. H. P. Blackmore and W. Whitaker, B.A., F.G.S.

To Sutton and Ewell, on May 1st, in association with the Sutton Scientific Society, under the direction of H. Hutchins French, F.G.S.

To Welwyn, on May 15th, in association with the Hertfordshire Natural History Society, under the direction of the President and John Hopkinson, F.L.S., F.G.S.

To Walton Common and St. George's Hill, on May 29th, under the direction of W. H. Hudleston, F.R.S.

To Dungeness, Rye, and Hastings, Whit-Monday and Tuesday, June 14th and 15th, under the direction of the President, J. E. H. Peyton, F.G.S., and George Wilks.

To Pinner and Rickmansworth, on June 26th, in association with the Hertfordshire Natural History Society, under the direction of John Hopkinson, F.L.S., F.G.S.

To the Maidstone District, on July 10th, in association with the Maidstone and Mid-Kent Natural History Society, under the direction of Prof. G. S. Boulger, F.L.S., F.G.S.

To Northumberland, from August 2nd to 7th, under the direction of the President, and Prof. G. A. Lebour, M.A., F.G.S.

The thanks of the Association are especially due to the following gentlemen for assistance and hospitality on the Excursions:—Dr. H. P. Blackmore, Salisbury; Mr. W. H. Hudleston; Dr. A. T. Brett, Watford; Mr. Grenville A. J. Cole, Science Schools; Mr. H. Stringer, Town Clerk of Romney; Mr. M. Heckels, Newcastle; Mr. J. Daglish, President, Mr. T. W. Bunning, Secretary, and the Members of the North of England Institute of Mining and Mechanical Engineers, Newcastle; Prof. Lebour, Newcastle; Mr. R. Middlemas, President of the Berwickshire Naturalists' Field Club; Mr. R. Howse, Newcastle; Mr. Denning, Newcastle; Messrs. Harrison and Forbes, engineers to the North-Eastern Railway; Sir William Armstrong, Rev. W. S. Wrenford, and Mr. D. Dixon, Rothbury; Mr. F. R. Wilson, the Rev. J. J. M. Perry, and many other residents in Alnwick; the Duke of Northumberland; Earl Grey; Sir Walter Riddell, Bart.; Mr. C. B. R. Bosanquet, Rock; Rev. W. W. F. Keeling, Holy Island; Rev. A. O. Medd, Banborough; Mr. L. Atkinson (on behalf of Messrs. Ford and Wright); and Mr. F. Schute, South African Section, Colonial and Indian Exhibition.

Your thanks are also due to the Council of University College for the privilege of meeting in their library, for the accommodation granted for our bookcases, as well as for permission to hold this meeting in their Mathematical Theatre, and for the use of the Medical Library each month for the Council.

Owing to the expiration of his term of office, Mr. Topley retires from the Presidential Chair. Never once absent either from the Council or the Ordinary Meetings, he has ever been watchful of the interests of the Association, which has prospered under the care and attention he has bestowed on its affairs. During his term of office he contributed two addresses of great geological interest, besides a 'Life of Prof. Morris,' whose loss we all so sincerely deplore. The excursions, led by Mr. Topley, to Dungeness, Rye, and Hastings, and to Northumberland, are not likely soon to pass from the recollection of those who took part in them, whilst the delightful excursion to Belgium, and the series of Conferences on the Mineral Resources of India and our Colonies, held at the Colonial and Indian Exhibition, owed their origin and success to his organization.

Your Council has much pleasure in nominating as his successor Mr. F. W. Rudler, F.G.S., Hon. Sec. Anthrop. Inst., Curator and Registrar of the Museum of Practical Geology, whose wide attainments and great learning are familiar to all. Though his writings have been confined for the most part to mineralogical and anthropological subjects, Mr. Rudler's knowledge of geology is both intimate and critical, whilst the Members have often been indebted to him for much kindly help readily given at Meetings, on Excursions, and in the Council; so that we feel sure that the Association cannot but prosper under his leadership.

An additional vacancy in the Council has been caused this year by the resignation of Mr. W. Fawcett, B.Sc., F.L.S., F.G.S., consequent on his appointment as Director of Public Gardens and Plantations in Jamaica. Need we add that he carries with him the good wishes of all for his success.

Another event of interest, and one which cannot be passed by in silence, is the change that was rendered necessary in the constitution of the Council by the partial retirement of Dr. Foulerton. For ten years Dr. Foulerton has carried on single-handed the ever-increasing task which the Secretaryship involves, and with what ability and success let the growth of the Association during that period testify; for, from 390 members at the end of 1876, it has now increased to 500, or by more than 25 per cent.; whilst the numbers attending the excursions have year by year augmented, so that an expedition of the Geologists' Association now implies quite a formidable party to conduct. It is, therefore, a matter of congratulation that Dr.

Foulerton's services may still be counted on in connection with our excursions, and that, though the charge of the ordinary business has devolved on other hands, we still have the benefit of his great experience and knowledge.

The Report of the Council was, after discussion, adopted as the Annual Report of the Association for 1886.

The following Officers and Council for the year 1887 were declared by the scrutineers to be duly elected:—

PRESIDENT.

F. W. Rudler, F.G.S., Hon. Sec. Anthrop. Inst.

VICE-PRESIDENTS.

H. Hicks, M.D., F.R.S.
T. V. Holmes, F.G.S.
Prof. F. Meldola, F.R.S.
W. Topley, F.G.S.

TREASURER.

J. Hopkinson, F.L.S., F.G.S.

SECRETARIES.

J. Foulerton, M.D., F.G.S.
B. B. Woodward, F.G.S., F.R.M.S.

EDITOR.

Prof. G. S. Boulger, F.L.S., F.G.S.

LIBRARIAN.

J. Bradford, F.G.S.

COUNCIL.

W. H. Bartlett, F.G.S.
Rev. Prof. T. G. Bonney, LL.D., F.R.S., F.G.S.
Prof. G. S. Boulger, F.L.S., F.G.S.
J. Bradford, F.G.S.
Rev. E. S. Dewick, M.A., F.G.S.
J. Foulerton, M.D., F.G.S.
H. H. French, F.G.S.
W. B. Gibbs, F.R.A.S.
G. F. Harris, F.G.S.
H. Hicks, M.D., F.R.S., F.G.S.
T. V. Holmes, F.G.S.
J. Hopkinson, F.L.S., F.G.S.
Prof. T. Rupert Jones, F.R.S., F.G.S.
H. M. Klaassen, F.G.S.
J. L. Lobley, F.G.S.
J. Love, F.G.S.
Prof. F. Meldola, F.R.S.
E. T. Newton, F.G.S.
F. W. Rudler, F.G.S.
W. Topley, F.G.S.
A. S. Woodward, F.G.S.
B. B. Woodward, F.G.S.

[*For Balance-Sheet see next page.*]

The thanks of the Association were unanimously accorded to the retiring President and members of Council, and to the Auditors. The Annual Meeting then terminated.

GEOLOGISTS' ASSOCIATION.

Income and Expenditure for the Year ending 31st December, 1886.

Dr.

	£	s.	d.
To Life Compositions	68	5	0
„ Admission Fees	34	0	0
„ Annual Subscriptions (£174 15s., less Subscriptions returned £2)	172	15	0
„ Dividends on £547 4s. 8d. Consols	15	17	6
„ Sale of Publications	17	18	0
„ Advertisements	1	10	0
	£310	5	6

Cr.

	£	s.	d.
By Balance due to Treasurer	10	9	4
„ Printing 'Proceedings'	120	12	11
„ „ 'Geology of Belgium'	2	10	0
„ „ Monthly Circulars	27	9	0
„ Illustrating 'Proceedings' and Circulars	10	16	3
„ Miscellaneous Printing	24	15	10
„ Postages	41	10	8
„ Addressing	10	1	0
„ Library	5	18	0
„ Fire Insurance for 1886 and 1887	3	15	0
„ Stationery	1	18	1
„ Trypograph	2	5	0
„ Attendance, Gas, &c., at Meetings	9	3	6
„ Conferences at Indian and Colonial Exhibition	5	4	0
„ Miscellaneous Expenses	0	19	5
„ Balance in Bank of England	32	17	6
	£310	5	6

We have this day examined the Accounts of the Treasurer of the Geologists' Association, and we find the above Statement to be correct.

(Signed) H. HUTCHINS FRENCH,
S. H. NEEDHAM, } Auditors.

21st January, 1887.

ORDINARY MEETING.

FRIDAY, FEBRUARY 4TH, 1887.

F. W. RUDLER, F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association:—

H. Bolton; C. Claremont; G. C. Crick, F.G.S.; G. E. East, jun.; H. E. Hoddinott; T. C. Luff; Col. C. A. McMahon, F.G.S.; D. Pidgeon, F.G.S.; and M. Noel Ridley, C.E.

The meeting then resolved itself into a Conversazione.

Among the chief objects exhibited were:—

A series of Fossils from the Chalk and Gault of Blue Bell Hill, Burham, Kent; specimens illustrating the manufacture of Portland Cement, and a Porter's Testing Machine; specimens of the various Marbles of Japan; specimens of Clay used in the manufacture of Doulton Ware; exhibited by Mr. S. J. HAWKINS (the last in conjunction with Mr. F. K. BIRD).

Minerals and Fossils; exhibited by Mr. S. PROUT NEWCOMBE and Mr. F. W. RUDLER, F.G.S.

Specimens from the Sunken Forest at Torbay; exhibited by Mr. D. PIDGEON, F.G.S.

Crystals examined by Polarized Light; exhibited by Mr. W. B. GIBBS, and Mr. J. LOVE, F.G.S.

Dunite from New Zealand, Proustite, Augite, &c.; exhibited by Mr. J. R. GREGORY.

A series of Microscopic Petrological Slides; exhibited by Mr. G. SMITH.

A section showing the junction of the Great Corndon Laccolite with the overlying Ladywell Schists; exhibited by Mr. C. J. ALFORD, F.G.S.

Minerals and Fossils; exhibited by Mr. J. H. LEONARD.

Microscope and Petrological Slides; exhibited by Mr. J. ALSTONE.

Microscope and Petrological Slides; exhibited by Mr. E. LAWRENCE.

Portable Microscope and Grains of Sand, with Crystallized Quartz, from Permian Sandstone; exhibited by Mr. H. M. **Klaassen**, F.G.S.

Photographs and Map of the District of Rotomahana, New Zealand; exhibited by Prof. J. W. **Judd**, F.R.S.

MS. Geological Map of the Lava Streams of Vesuvius, and Photographs of Vesuvius and Bay of Naples; exhibited by Dr. H. J. **Johnston-Lavis**, F.G.S., &c.

Photographs illustrating Scenery of West Yorkshire and Scotland; exhibited by Mr. G. **Barrow**, F.G.S.

Photographs illustrating Scenery of Neighbourhood of Settle, Yorkshire; exhibited by Mr. George J. Jones.

During the Conversazione the following addresses were given:—

'On the recent volcanic outburst in New Zealand,' by **Wm. Lant Carpenter**, B.A., B.Sc., illustrated by lantern views belonging to himself and Prof. Judd, F.R.S.

'On Agates and their formation,' by Mr. W. J. **Abbott**, illustrated by nearly 300 specimens.

The Quekett Microscopical Club kindly granted the use of their lamps for the evening.

ORDINARY MEETING.

Friday, March 4th, 1887.

F. W. **Rudler**, F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association:—

M. H. Douglas; Dr. F. H. Hatch, F.G.S.; P. Roscoe; and G. P. Wight.

The following paper was then read:—

'A revision of our Lower Eocenes.' By G. F. Harris, F.G.S.

Specimens were exhibited by Mr. Harris in illustration of his paper.

A Revision of our Lower Eocenes.

By Geo. F. Harris, F.G.S.

The Lower Eocene formations of the British Isles are situated in four different regions—1. The London basin; 2. The Hampshire basin; 3. The Isle of Mull and the neighbouring parts of Scotland; and 4. The North-East of Ireland.

The principal subject of the present communication is the London basin, which is, roughly speaking, a triangular patch of clays, sands, and gravels, lying on the Chalk, and the edges of which extend in a westerly direction from Pegwell Bay (near Ramsgate) through Rochester, Croydon, Basingstoke, to Hungerford; thence north-eastwards through Reading, Windsor, Watford, by Hertford and Woodbridge to the eastern part of Norfolk by Great Yarmouth. The estuary of the Thames occupies the site of a large portion of the beds which have been denuded by that river and by the sea on the eastern boundary of the basin in Essex, Suffolk, and Norfolk.

Many geologists have described portions of the area under consideration, amongst the earlier of which we might mention Mr. J. Parkinson, "Observations on Some of the Strata in the Neighbourhood of London and on the Fossil Remains contained in them" ('Trans. Geol. Soc.,' 1811, Ser. 1, Vol. i, p. 324); Rev. Prof. W. Buckland, "Description of a Series of Specimens from the Plastic Clay near Reading," &c. ('Trans. Geol. Soc.,' 1817, Ser. 1, Vol. iv, p. 277); Prof. Morris, "Observations on the Strata near Woolwich" ('Mag. Nat. Hist.,' Vol. viii, 1835, p. 356); "On the Strata usually termed Plastic Clay" ('Proc. Geol. Soc.,' Vol. ii, 1837, p. 551); Rev. H. M. De la Condamine, "On the Tertiary Strata and their Dislocations in the Neighbourhood of Blackheath" ('Q. J. G. S.,' Vol. vi, 1850, p. 440); Mr. N. T. Wetherell.

The general structure of the beds between the London Clay and the Chalk, however, in spite of the careful researches above mentioned, was but very imperfectly understood before Professor Prestwich took up the subject in great detail, and laid the results of his masterly observations before the Geological Society in the following three memoirs: Part I. "The Basement Bed of the London Clay" ('Q. J. G. S.,' Vol. vi, 1850,

p. 252); Part II. "The Woolwich and Reading Series"* ('Q. J. G. S.,' Vol. x, 1854, p. 75); Part III. "The Thanet Sands"† ('Q. J. G. S.,' Vol. viii, 1852, p. 235). These memoirs have been largely used in the works of subsequent observers. Sir Chas. Lyell wrote on "The Blackheath Pebble-Bed, and on Certain Phenomena in the Geology of the Neighbourhood of London" ('Proc. Roy. Inst.,' Vol. i, 1852, p. 164; and 'Edin. New. Phil. Journ.,' Vol. liii, p. 94); Mr. C. Rickman on "Fossil Remains from Tertiary Strata at Peckham and Dulwich" ('Geologist,' Vol. iii, 1860, pp. 151, 211), and on "The Lower London Tertiaries in the same Districts" ('Q. J. G. S.,' Vol. xvii, 1861, p. 6; 'Proc. Geol. Assoc.,' Vol. i, 1861, p. 106).

The next great series of works on the subject were those of Mr. Whitaker, whose several important memoirs—"On the Western end of the London Basin," &c. ('Q. J. G. S.,' Vol. xviii, 1862, p. 258); "The Tertiary Beds of Kent" ('Geologist,' Vol. vii, 1864, pp. 57, 157); and "On the Lower London Tertiaries of Kent" ('Q. J. G. S.,' Vol. xxii, 1866, p. 404)—culminated in the standard work on the "Lower Eocenes of the Southern and Western Portions of the London Basin" ('Mem. Geol. Surv.,'‡ Vol. iv, Part I, 1872). This has been supplemented, as the north-eastern part of the basin was worked out, by short official memoirs, largely written by Mr. Whitaker, but also by Messrs. W. H. Dalton, F. J. Bennett, and J. H. Blake, by which our knowledge of that portion of the area has been very considerably augmented. Mr. H. M. Klaassen has minutely described a "Section of the Lower London Tertiaries at Park Hill, Croydon" ('Proc. Geol. Assoc.,' Vol. viii, 1883, p. 226), and Mr. E. T. Newton has added an appendix on a new species of *Perna*, and on *Coryphodon* remains from the Woolwich beds in the same section (*ibid.*, pp. 248, 250). Numerous other valuable papers will be found in our Proceedings. Mr. Starkie Gardner has written "On a Revision of the British Eocenes" ('Geol. Mag.,' Dec. II, Vol. ix, 1882, p. 466); "On the Section between

---

* 'With a Description of New Species of Shells,' by Prof. Morris, p. 157; 'Notes on the Entomostraca,' by Prof. T. Rupert Jones, p. 160; and 'A Note on the Fossil Plants from Reading,' by Dr. J. D. Hooker, p. 163.

† 'With a Description of Fossil Shells from the Lower Thanet Sands,' by Prof. Morris.

‡ Complete lists of references up to date will be found in this work.

Herne Bay and Reculvers" ('Q. J. G. S.,' 1883, pp. 197-210), and other memoirs.

Before attempting to give the views of the various authors referred to, let us get some idea of what the beds are like. We will commence by generalizing those in the western part of the area, working thence eastwards.

We find in the neighbourhood of Hungerford and Reading a very variable series of beds lying between a massive argillaceous deposit, known as the London Clay, and the Chalk. After examining a large number of sections in them, a sort of general sequence is made out, which may be indicated in the following manner:—

West of the London Basin.

1. Thick mass of clay (London Clay).
2. Shingles, sands, and clays.
3. Mottled clays and sands.
4. Shingles, sands, and clays.
5. Chalk.

No description can be drawn up which shall be applicable, even in a general sense, to all the sections in which beds 2 and 4 are seen. Sometimes a pebble bed underlies the London Clay, at the base of which is a series of more or less pure sands and clays, this being followed by mottled clay; whilst at others the pebble-bed is absent and a thick mass of sand occurs in its place. The mottled clay itself is by no means a massive sheet of clay of a certain thickness. It often does occur as a thick bed of clay of a red, green, and yellow mottled appearance; but it is just as often cut up by seams of sand; whilst occasionally, as in the railway cutting at Reading, it is in lenticular patches. Moreover, it is often found resting unevenly on the sands and shingle below, and now and then approaches to within six or seven feet of the Chalk. The sequence alluded to holds tolerably well until the neighbourhood of Epsom is reached, when bed 4 develops a thick mass of sand at its base. In this region also and to the south-westward a bluish-black clay makes its appearance above the mottled clay; but things do not begin to get very clear until Croydon is reached. We then find that the incoming of other beds renders the general sequence of the beds in the western part of the basin unrecognizable in this district. A new order obtains, which might be thus expressed :—

*Croydon District.**

1. Thick mass of clay (London Clay).
2. Thick sand laminated in parts.
3. Very thick pebble-bed, with shell bed at the base.
4. Blue clays full of shells, mostly broken.
5. Mottled clay.
6. Clayey sand with pebbles, especially at the base.
7. Very thick sands.
8. Chalk.

These divisions hold good until we near Lewisham. We there find that the pebble-bed (3) has dwindled away to six inches in thickness, and that bed 2 has become more laminated, having thin clay partings throughout. Bed 4 becomes very much sub-divided, having sand and lead-coloured clay with lignite in its upper part. The mottled clay (5) requires the eye of faith to detect it in its proper place. Bed 6 has developed an enormous mass of shingle, rather sandy and argillaceous at its base.

Woolwich District.—On reaching Charlton the relation of the London Clay to the thick laminated sand (bed 2) is not very clear, by reason of the absence of a good section of the junction. But we find a very thick pebble-bed, which probably corresponds with bed 3, in the Croydon district, resting unevenly on a bed of sand which lies on the blue clays (bed 4). The mottled clay, as at Lewisham, is indistinctly represented.

On Blackheath a very thick pebble-bed is found; but, so far as I am aware, no fossils have been found in it at that place. It is much to be desired that the exact position of this pebble-bed should be ascertained with reference to the other beds in the district. It is generally stated that its horizon is immediately under the basement bed of the London Clay, and that it occasionally eats its way through the blue clays (bed 4), and lies unconformably to the beds beneath, examples being cited from Greenwich, Abbey Wood, Sundridge tunnel, &c. At Bostal Heath, near Plumstead, there can be no doubt that a pebble-bed is found on the side of the hill, resting on bed 6. The same might be said with regard to it at other places between Plumstead and Erith. When we arrive at the latter place we find that the succession of the beds is the same as at Charlton. The mottled clay is more pronounced, but bed 6 is not so well shown. It is mostly a sandy pebble-bed.

---

* See Klaassen, 'Proc. Geol. Assoc.,' Vol. viii, 1883, p. 248, for details.

Upnor District.—At Upnor, near Rochester, there are good exposures from the London Clay to the middle of the Thanet beds, whilst the Chalk may be seen a short distance to the south of the largest sections. The whole of the beds dip at a low angle to the northwards. Their sequence is somewhat different from that at Erith, or, rather, the characters of some of the beds are changed. We may indicate it by the following :—

Upnor District.

1. Thick massive London Clay, with pebbles at the base.
2. Light buff sand, with scattered pebbles.
3. Bed of well-rounded pebbles, with shells.
3*a*. Thick sandy bed, with bands of clay in places.
4. Blue clays, with broken shells and very thin streaks of sand.
5. *a*. Laminated sand and clay.
   b. Fine white sand.
   c. Lilac-coloured sandstone, not very compact. Lignitic.
6. Thick mass of false-bedded sand, with thin pebble-bed at base.
7. Very thick buff-coloured sand.
8. Chalk.

A comparison of this section with that at Croydon will show that the general order of succession is practically the same. The principal difference is that the mottled clay is here replaced by other beds, included under 5. It is useful to notice the persistence of the lilac-coloured sandstone in passing. This bed, which is lignitic in places, is met with in the same position many miles from Upnor, and serves as a guide in working out the sequence. It has been seen *in situ* near Green Street Green (on the Swanscombe Park outlier, about half way between Erith and Upnor); on the Cobham outlier; near Sittingbourne, and at many other places, some of which will be hereafter mentioned. There are very few sections of any importance between Upnor and Boughton-under-Blean, five miles west of Canterbury, except near Sittingbourne, where beds 2, 3, 3*a*, 4, and 5 are seen, presenting nearly the same features as at Upnor.

Canterbury District.—The sections at Boughton are not so easily disposed of, and it will be seen that I differ from previous observers in the explanation of the divisions into which the beds should be placed. Beds 2 and 3 occur, but not quite as at Upnor. In a pit near the 50th milestone on the London road * a series of sandy clays of a dark colour occur, cut up by frequent thin beds of whitish-yellow and green sand (causing the sandy clay to assume lenticular shapes in some places). The base of this bed is very dark, almost black, and ferruginous, and rests on a bed of greenish-brown sand. The general appearance of this bed is such as to suggest that it is the equivalent of the blue clays, with broken shells and thin, sandy streaks (4) at Upnor. This does not hitherto appear to have been recognized, and the result is that the bed has been placed higher in the series than is the bed 4 alluded to at Upnor. Its position, with reference to underlying beds, is exactly the same in the Boughton and Upnor sections. For instance, 5 *a*, *b*, and *c* occur, and are very easily recognized, the lilac-coloured sandstone being present. Between 5 *b* and *c* a very thin pebble-bed occurs. Beds 6 and 7 are seen farther down the road, and the whole succession is proved by many sections near the outcrop of the main mass of Lower Tertiaries.

We next come to Canterbury, where we find bed 2, a light buff sand, rather ferruginous at the base (the remains, perhaps, of 3*a*), and with a thin bed of small pebbles. Bed 4 is very ferruginous and sandy. Beds 5 *a* and *b* have nearly thinned out, there being only slight indications of 5*b*, and the thin pebble-bed which occurs at Boughton between 5 *b* and *c* is also present, and contains pieces of the lilac-coloured sandstone, 5*c*. Beds 6 and 7 are as usual, but a bed of argillaceous matter is found at the base of the latter. This we will call 7*a*.

Herne Bay District.—The next section claiming our attention is the finest exposure of the Lower Eocenes in the London basin, viz., between Herne Bay and Reculvers. We there find that bed 1 is present in force, with a few pebbles, and much lignitic matter at its base, as usual. Bed 2 is well developed, whilst 3 and 3*a*, as might have been expected from the foregoing remarks, have disappeared. Bed 4 is present, perhaps, in the shape of a thin deposit of clay and sand, much iron-stained as usual, whilst the pebble-bed below it (in 5) has thickened out. This pebble-bed is much divided up in places by lenticular patches of sand, and both it and bed 4 are liable to vary in thickness. Beds 6 and 7 are clearly shown, and 7*a* occurs in a well-section at Reculvers. At Pegwell Bay we get 7 and 7*a* in a good exposure.

---

* See 'Mem. Geol. Surv.,' Vol. iv, Part I, p. 267.

We have now roughly described the beds which occur between the London Clay and the Chalk, from Hungerford to the east of Kent. It now remains for me to say a few words respecting the exposures of these beds in Hertford, Suffolk, and Norfolk. There are some very good sections about Watford, and the general sequence, although not strictly comparable, is like that in the western part of the basin (see p. 42), viz., a mottled clay between two beds of sand, clay, and shingle. I have not seen the exposures in Suffolk and Norfolk. Much of the beds is covered up by newer deposits. It is interesting to note that the officers of the Geological Survey, however, have described in the neighbourhood of Ipswich the true mottled clay, with sand, &c., both above and below it, in many sections, the principal of which, perhaps, is to the north of Bramford Station.* The sands above the mottled clays generally appear to be very well developed, and contain pebbles in this district.

We have now to consider briefly the palæontology of the different beds. Taking the western part of the basin first, we shall find that 4 (p. 42) is decidedly marine in character. It contains hardly anything but marine fossils, and these, with the exception of *Ostrea* and sharks' teeth, are rare. In the vicinity of Epsom certain of the beds comprised within it contain tube-like markings. Anyone familiar with the "tubes of annelids," found in such great abundance in the Belgian Lower and Middle Eocenes, will have no difficulty in recognizing them as such. Bed 6, in the Croydon and Upnor sections, is a further development of this bed 4, and, as will be remembered, the same bed (6) is found at Herne Bay.

---

* 'Geol. of Ipswich, Hadleigh, and Felixstow,' by W. Whitaker, B.A., F.G.S., &c. (1885), p. 14.

Throughout its extent it is marine, being in the last mentioned section replete with fossils, especially at the base, and no doubt can possibly creep in as to its origin. We may mention that exactly the same may be said of bed 7, which is very fossiliferous at Pegwell Bay, Herne Bay, and Upnor, and in which one or two marine shells have also been obtained from Erith * and Charlton. Retracing our steps to Reading, we find that bed 3 (p. 42) contains a fine flora at its base. So far as I am aware, no other fossils have been obtained from the mottled clay, so we have only to judge of its origin from the character of the deposit. It is generally admitted to be of fresh-water origin. The blue clays, bed 4, from Croydon to Upnor contain mostly fresh-water and estuarine fossils, such as *Cyrena*, *Cerithium* (*Potamides*), *Paludina*, *Melania*, &c. A few stray marine genera creep in, and a thick oyster bed is a common feature. The fossils, no less than the character of the beds, lead us to believe that they were deposited in the estuary of a river, where the sea and fresh water alternately gained the ascendancy over each other. A point to which I would particularly draw attention is that what I believe to be bed 4 in the section at Boughton-under-Blean (p. 45) has produced a rather more than usual abundance of marine shells. † We still find the estuarine *Melania*, *Cerithium*, *Cyrena*, &c., but they are accompanied by such well-known marine genera as *Aporrhais*, *Pyrula*, *Astarte*, *Cardium*, *Corbula*, *Cyprina*, *Cytherea*, *Panopæa*, &c. It would, therefore, appear that as the bed 4 goes eastwards it becomes less argillaceous and more marine in character. At Herne Bay this bed, like the pebble-bed below it, contains only sharks' teeth. The blue clays referred to are distinct from the mottled clays in point of age, that is to say, they do not coalesce, as might be thought at first sight. This is proved by their respective floras, that of the former being of a younger type (approaching more to that of the London Clay) than the latter. Whatever difficulties there may be in separating these two series of deposits at any particular place, this conclusive evidence is not thereby affected.

---

* On the occasion of the excursion to Plumstead, on the 16th July, 1887, under the direction of Mr. Goodchild, some Members of the Association were fortunate enough to discover the shells or casts of *Modiola*, *Pectunculus*, *Cyprina*, *Cytherea*, *Cardium*, and *Ostrea* in this bed at Plumstead Station.

† See Prestwich, 'Q. J. G. S.,' Vol. vi (1850), p. 264.

The pebble-bed at Croydon (3), and its equivalents in the Charlton (3) and Upnor (3) sections, contain fossils which are practically the same as those of bed 4. It is true that a few more marine types are found in it than in bed 4, yet anyone who has worked in the two beds is aware of the fact that the general facies of the one is exactly that of the other—*Cyrena*, *Melania*, and *Ostrea* being the common fossils in both.* Both beds get more marine in character as they go eastwards. A point of interest is that in the Upnor section the pebble-bed is rather weakly developed. In some parts of the section, indeed, it is altogether missing, and I believe it practically disappears before getting to East Kent, a few scattered pebbles only being developed. At Herne Bay bed 2 contains hardly any but marine fossils. I have found *Cyrena cuneiformis*, however, from it, in the collection of Mr. W. J. Abbott. With reference to the bed of sand with clay partings, found immediately under the London Clay at Croydon, Lewisham, and Bromley (bed 2), it contains a flora, which, so far as is known, is intermediate between those of the blue clays and the London Clay. The only beds with which we have not now dealt from a palæontological point of view are the sands and shingles forming bed 2 (p. 42) in the western part of the basin. So far as is known, these are marine in origin. Estuarine species have been found, but are exceedingly rare. Immediately under the London Clay the beds are sometimes very fossiliferous, being decidedly marine. One is inclined to think, however, from their intimate association with the mottled clays, that some of the sands just above the clays are of fresh-water origin, or at least estuarine.

We will now endeavour to show how the beds between the London Clay and the Chalk have been correlated. In doing so, we will chiefly consider the views of Prof. Prestwich, Mr. Whitaker, and Mr. Gardner. The first-mentioned observer, as before stated, laid the foundations of the study of these Lower Eocenes, and the manner in which he divided the beds, as contrasted by the later classification of Mr. Whitaker, may be conveniently expressed by the following table :—

---

* It may here be mentioned that Mr. Searles Wood ('Mon. Pal. Soc. Eocene Mollusca, Bivalves,' Supplement) calls into question the existence of *Cyrena britannica*, Sow., as he had never seen the shell. Mr. Jas. T. Day has obtained a perfect specimen, whilst I have found four fragments of it in the sand at the base of the pebble-bed (3) at Charlton.

Prof. Prestwich, 1850-54.				Mr. Whitaker, 1866.*
London Clay.		Clay.		
Lower London Tertiaries.	Basement Bed of the London Clay.	*a*. Thin pebbly loam, &c., of the western part of the London Tertiary District.	Basement Bed.	London Clay.
		b. Thin clayey pebble-bed of Lewisham, &c.		
		c. Highest sands of Upnor, the Reculvers, &c., with pebbles at the bottom.	Oldhaven (and Blackheath) Beds.	Lower London and Kentish Tertiaries.
		d. Part of the sandy pebble-bed of Kent (Blackheath, Abbey Wood, Shottenden Hill, &c.).		
	Woolwich and Reading Series.	*e*. Part of the sandy pebble-bed of West Kent (Sundridge, near Bromley).		
		f. Sands, shell-beds, mottled clays, lower pebble-beds (unfossiliferous and local), and pebbly green sands of West Kent, and part of East Kent.	Woolwich and Reading Beds.	
		g. Mottled plastic clays, sands, &c., of the western part of the London Tertiary District and sands of East Kent.		
	Thanet Sands.	*h*. Sands, sandy marls, &c., &c.	Thanet Beds.	

Mr. Whitaker, as will be seen, created a new name (or names), the Oldhaven and Blackheath beds,† out of part of Prof. Prestwich's Basement Bed of London Clay and part of his Woolwich and Reading Series. His reason for so doing was his belief that the Oldhaven and Blackheath beds were both stratigraphically and palæontologically capable of separation, as a distinct series of deposits from the other beds. The irregularity of the Blackheath pebble-bed, which, he states, often cuts through several members of the underlying Woolwich and Reading Series (examples being cited from Greenwich, Bromley, Abbey Wood, &c.), lead him to think that an unconformity exists between that pebble-bed and the underlying series. He also believed that the sands below the

---

* 'Q. J. G. S.,' Vol. xxii, cited in Phillips' 'Manual of Geology,' by Robt. Etheridge, F.R.S. (1885), p. 607.

† 'Quart. Journ. Geol. Soc.,' Vol. xxii, p. 412.

London Clay at Herne Bay, &c., showed an assemblage of fossils distinct from those of either the Woolwich and Reading beds or the London Clay. A deposit of sands with clay partings at Bromley, which contains leaf-beds, was considered of fresh-water origin; and the pebble-bed, with estuarine fossils, at Charlton, and the marine sands of Herne Bay just alluded to, were all comprised in his Oldhaven beds. The Oldhaven and Blackheath Series were, therefore, of fresh-water, estuarine, and marine origin. He thought that the pebble-bed in the series was formed, not on a mainland beach, but a little way out at sea. He also says that the Woolwich beds sometimes lie on eroded surfaces of the Thanet beds, that the upper members of these Lower Tertiaries often overlap the lower ones, and that there is no stratigraphical unconformability between the Thanet beds and the Chalk. The lowest member of the Thanet Series, he says * is the bed containing the unrolled green-coated flints, which is remarkably persistent throughout the basin, and he believes that it may have been formed after the deposition of the beds above by the dissolving away of the Chalk by percolating water and the consequent leaving behind of its contained insoluble flints. Prof. McKenny Hughes † and others have written also on this subject. Mr. Whitaker is also of opinion that the Woolwich and Reading strata are so intimately associated with each other that it is impossible to separate the two series.

Mr. Gardner, on the other hand, maintains ‡ that the Oldhaven beds of East Kent should be added to the London Clay, being merely a lower member of the latter Series, as was implied by Prof. Prestwich's name for them ("Basement-bed of London Clay"). The most remarkable thing, however, is that Prof. Prestwich brackets his "basement-bed" not with the London Clay, but with the beds below to form the "Lower London Tertiaries." Mr. Gardner says that "We see by the Survey list of fossils § that the fauna (of the Oldhaven beds) was intermediate between those of the London Clay and the Thanet beds, for only two species are now not known to range beyond it; seven of the species range downward only, 12 range both up and down, and 13 range upward only; so that it is united by 75 per cent. of its

* 'Mem. Geol. Surv.,' *op. cit.*, p. 56.
† 'Q. J. G. S.,' Vol. xxii, p. 402.
‡ 'Quart. Journ. Geol. Soc.,' *op. cit.*
§ 'Mem. Geol. Surv.,' *op. cit.*, Vol. iv, p. 579.

species with the London Clay and by 50 per cent. with the Thanet beds." The part of the classifications of Prof. Prestwich and Mr. Whitaker to which Mr. Gardner takes the most serious objection, however, is with reference to the bed immediately above the Thanet Sand of those observers. It is the bed which I have numbered 4 in the western part of the basin (p. 42) and 6 at Croydon, Upnor, and Herne Bay, and is called the "Bottom-bed" of the Woolwich and Reading Series by Mr. Whitaker and others. As has before been stated (p. 47), this bed is marine throughout its extent from Hungerford to Herne Bay, whilst the remaining part of the Woolwich and Reading Series, above it, is either fluviatile or estuarine. Both Prof. Prestwich and Mr. Whitaker agree that it is difficult to separate this "bottom-bed" from the Thanet beds in the east of Kent, but, on the ground that it lies irregularly on the Thanet, and is distinct from it lithologically in so many places in West Kent and in the London area, they think it should be classed with the Woolwich and Reading Series rather than with the Thanet. Mr. Gardner, however, is of opinion that, being of marine origin, like the Thanet beds, being so closely allied with the latter palæontologically, and the bases of separation, as defined by previous observers, being so slight, this "bottom-bed" should be classed with the Thanet beds. He says * that "Of 57 specifically determined bivalves of the Thanet Sands 13 pass into the so-called marine division of the Woolwich and Reading beds, while of 12 bivalves from the latter only two—*Cardium Laytoni*, Morr., and *Teredo antenautæ*, Sow.—do not pass down into the Thanet beds. If the Survey list is accurate there is thus no marked palæontological break in the marine series." Mr. Gardner also thinks that the Reading beds (mottled clay, &c.) can be distinguished from the Woolwich (blue clays, &c.) by means of their floras, there being no data furnished for comparison of their faunas, as the mottled clay contains no other fossils than plants. He believes that there is an unconformability between the Chalk and the Thanet beds, as "even the highest Chalk must have been greatly denuded before it was compressed into a solid rock;" that in pre-Thanet times, where the water was shallow enough to permit the growth of sea-weed on the Chalk, sediment would ultimately be deposited on such a sea-weed covered surface, and that this imbedded vegetable matter may well account for the peculiar character of the blackish-green mud-like sediment in which the green-coated flints are found. This bottom bed, he observes, might, of course, belong to a very much older period than the rest of the Thanet beds.

---

* *Op. cit.*, p. 205.

We will now examine the various points that have been raised. To begin with the bed immediately above the Chalk (the bed of green-coated flints, &c.). I do not see how it can be classed with the Thanet beds, because inasmuch as the bed with flints is generally admitted to have been formed subsequently to the deposition of those beds by the action of percolating water on the Chalk containing the flints, it cannot possibly—if this theory be the correct one, and I think it is—be wholly of Thanet age. There is no reason why the bed of green-coated flints should not be forming even at the present day. I believe that it should be classed with the Cretaceous beds below. It is merely a case of the abstraction of certain portions of a deposit in a manner similar to that which has removed fossil shells and calcareous matter generally from many portions of the Thanet (and other deposits). In such a case the Thanet beds would still remain of Thanet age after such abstraction had taken place. There would be no *à priori* reason for placing the Thanet beds with any overlying series, simply because of the abstraction of a certain amount of lime. So also with these green-coated flints; the only difference being that a greater quantity, perhaps, of lime has been removed. It would be a different matter if the flints were the products of denudation. With regard to the green clay, &c., it appears to me to be largely the particles of impurities, &c., brought through the sand by the action of water, which on arriving at the Chalk was filtered, and so the particles were left behind. Some of it may be, and most probably is, the remains of insoluble matter, other than flint, which was contained in the Chalk itself. Moreover, such green clay, &c., is not present in any appreciable quantity in many sections showing the junction of the Chalk with the Thanet, although the green-coated flints almost invariably are. I do not include the bed numbered 7*a* (p. 45) in these observations. This may be regarded as the oldest Eocene bed in the London basin, so far as we know at present.

Coming now to the question of the correlation of the "bottom-bed" of the Woolwich and Reading Series of Prof. Prestwich and Mr. Whitaker, I am almost entirely of Mr. Gardner's opinion that it should be removed from that series and placed in the Thanet beds, for the same reasons which he has advanced. There is only one suggestion which I would make, viz., that as the upper part of this so-called "bottom-bed" contains carbonaceous matter, especially at Herne Bay, it may be the representative of the bed numbered 5*c* at Upnor (see p. 44). It is in a corresponding position. If this be so, it is the equivalent of the mottled clay in the Herne Bay section.

The next point to which attention may be drawn is the correlation of the blue clays (4) in the Upnor section with the black ferruginous sandy-clays with sand partings in the Boughton-under-Blean district.

Every observer, so far as I am aware, agrees that the bed numbered 4 in the Croydon, Charlton, and Upnor sections is the Woolwich blue clay with fossils. After passing Upnor, however (going eastward), they assert that this blue clay dies out, the last place in which it is seen being in the neighbourhood of Sittingbourne. If this were the case it would not, of course, reach Boughton, as I have suggested. The bed numbered 4 in the sections of the last-mentioned district, and which I believe to be the eastward extension of this blue clay, is included in the basement bed of the London Clay by Prof. Prestwich,* and in the Oldhaven beds by Mr. Whitaker; † though it is difficult to see on what grounds. Everybody admits that there is a general tendency of the Lower Eocenes of the London basin to become more marine in character as they go eastwards ; and I regard the black ferruginous clay and sand alluded to, as the more marine equivalent of the estuarine blue clays further westward. The bed at Boughton, as previously stated, still contains a large proportion of estuarine fossils mixed with marine. Not only is the palæontological evidence in favour of this view to a slight extent, but the lithological character of the deposit, and its position with reference to under and overlying beds are so also. It is true that the ferruginous clay is rather more arenaceous in some sections than in others, yet its argillaceous character is not obliterated, but, on the contrary, is well marked in some of the sections. As we have already seen (p. 45), the position of this ferruginous clay and sand, with reference to the sands and lilac-coloured sandstone below, is identical in both the Upnor and Boughton sections. Its horizon is, therefore, clearly shown. The ferruginous bed in question can be traced at intervals along the southern outcrop of the main mass to Canterbury, and is found at the latter place in the same position. The succession is equally clear at Herne Bay. It has also been shown (pp. 45-6) that the pebble-bed found below it at Herne Bay can be recognized also at Boughton and Canterbury. This pebble-bed bears no relation, I believe, to the pebble-bed (3) at Upnor, or the equivalent bed in the Charlton and Croydon districts. I differ on this point from previous observers, and my reasons are quite obvious from what has been said respecting it.

---

* 'Q. J. G. S.,' Vol. vi (1850), p. 264.

† 'Mem. Geol. Surv.,' Vol. iv, pt. 1 (1872), pp. 266-8.

We now come to the consideration of the alleged unconformability of the pebble-bed on Blackheath to the beds on which it lies, examples of the irregularities of its occurrence having been cited (p. 43). It will be remembered that the creation of the Blackheath series is largely dependent on the value of the evidence afforded by this pebble-bed; and it is, therefore, of the first importance that the question of whether there is, or is not, an unconformability should be inquired into. It may here be mentioned that quite recently Mr. J. G. Goodchild* has strongly advocated the existence of a stratigraphical break between the Woolwich and Reading Series and this pebble-bed. He furthermore (in common with others) considers that the palæontological break between the Chalk and the Thanet beds is not so great as has generally been supposed. With this last remark I am rather inclined to agree, because it is obviously unfair to compare the fauna of a limestone with that of a sand. The fauna of the Thanet beds ought strictly to be compared with that of the Upper Greensand, but the latter is so far removed by reason of the interposition of the Chalk that it is difficult to realize this, whilst the evolution and migration of the species has been such as to render the comparison somewhat unfruitful. At the same time, although we may believe that the palæontological break at this point has been overrated, it is quite marked enough to enable us to draw a line between the Chalk and the Thanet, in preference to any other horizon, to separate the Secondary from the Tertiary beds. We have already seen that there is other evidence indicating an unconformability between the two formations alluded to, and if anything further is desired it is only necessary to point to the beds deposited in Belgium, close by, between the equivalents in that country of our highest Chalk and our Thanet beds. We shall then find that the Maestrichtien, Tufeau de Ciply, &c., and Calcaire grossier de Mons were deposited in the interval. Surely, the evidence is conclusive enough.

---

* 'Proc. Geol. Assoc.,' Vol. ix, pp. 213-214.

And now as to whether the Blackheath pebble-bed is unconformable or not to underlying deposits. In considering a question of this nature, we have, in the first place, to be quite sure that we are dealing with a pebble-bed the exact horizon of which is known. Now, can the horizon of the pebble-bed stretching from Greenwich by Blackheath to Plumstead and Erith be correctly ascertained? We must remember that the bed alluded to lies mostly at the surface, and it is in this position that it chiefly presents the phenomena of cutting into other beds. In many of these cases it is unfossiliferous, and in others it appears to me that it is impossible to fix its exact horizon. It is generally assumed by the surveyors that the pebble-bed occurs below their "basement bed of the London Clay," and in some cases this may be correct. It will be as well to point out, however, that pebble-beds occur on other horizons in these Lower London Tertiaries in the same district as that now under consideration, and that it is not at all times clear which of these pebble-beds crop out on the hill-sides, though such, on coming to the surface, are generally recognized as the Blackheath pebble-bed. At least three different pebble-beds are found in the strata hereabouts, the first being immediately at the base of the London Clay as at Loam Pit Hill, Lewisham; the second in the sand with clay partings above the blue clays;[*] and the third at the top of the Thanet beds in the Loam Pit Hill section.[†] Whether all the surface pebble-beds were formed in the Lower Eocene period is also a moot question. Pebble-beds of a similar nature do occur in the Bagshot and subsequent deposits. Another element which creeps in is as to how far some of the shingle has been slightly shifted by various agencies in recent times. Many of the pebble-beds between Greenwich and Erith suggest this, and they lie at suspiciously high angles on the hill slopes. But even supposing that the assumed horizon of these surface pebble-beds is the correct one, and not open to doubt as I have suggested, I cannot think that the mere circumstance of an estuarine pebble-bed having cut its way through a few feet of deposits, and resting irregularly on another and lower deposit, is sufficient grounds for showing an unconformability. The very action which brought a pebble-bed to the spot at all, would have been quite capable of scooping out such light sandy materials. It might be otherwise if we were dealing with a series of purely marine beds. The deposits under consideration, as pointed out, are estuarine in origin, and are regarded as the delta of an enormous river. Everybody is aware of the irregularities of river and estuary deposits, which are largely dependent in their development on the velocity of the stream at different periods. Heavy rainfalls in the river-basins are powerful agents in effecting these changes. Is it because a very rainy season renders the river suddenly more turbulent than ordinary, and causes a rather abnormal amount of irregularity in the deposits ; or because the silt chokes up one of the mouths of the river so that it eventually bursts through in a new place, or enlarges a little-used channel, that the result is an unconformability, and one, too, of such magnitude as to involve the creation of a distinct geological formation? A study of the works issued in recent years by the United States Geological Survey * soon convinces us of the character and appearance presented by the deposits of rivers and lakes of great magnitude; and if an unconformability were to be drawn at every such irregularity there would be endless confusion. In some cases, no doubt, where palæontology demands it, such a break may be conveniently made, but in the case of the Blackheath pebble-bed now before us there is no such demand. The fossils are almost identical with those of the Woolwich and Reading Series below, and there is, therefore, no reason for separating the two deposits from each other.

---

[*] Well developed in a section over the railway tunnel at Charlton.

[†] 'Mem. Geol. Surv.,' *op. cit.*, p. 127, beds 10 and 11.

Turning to the Oldhaven Sand of Mr. Whitaker. We have seen that palæontologically it is intermediate between the Thanet beds and the London Clay (see p. 50), and have also seen its position with reference to the black clays. I should not have much hesitation in correlating it with the London Clay, as does Mr. Gardner, except that no passage bed is observable in the Herne Bay section, where they are best examined. On the contrary, the base of the London Clay is very lignitic at that point, and is sharply marked off from the sand alluded to. All these things tend to show that there is no gradual passage between

---

* *e.g.*, '**Mon. U. S. Geol. Surv.**,' Vol. xi (1885).

the sand and the clay, as should be the case if this sandy bed is to be regarded as an integral part of the London Clay formation. At the same time I do not apprehend that there is a break of any importance; but, as both the palæontological and stratigraphical evidence seem in favour of it, we may class this bed with the Woolwich and Reading Series;* and I believe it is, therefore, together with the argillaceous and pebble-beds below, the marine representative of that series in East Kent. The only divisions of the Lower Eocenes, therefore, that seem to me admissible in the London basin are:—

1. London Clay.
2. Woolwich and Reading Series.
3. Thanet Series.

With regard to the Lower Eocenes of the Hampshire basin, we know so little about the lowermost members that it is safe to adhere to the present nomenclature, though the sand resting on the Chalk in some places suggests the occurrence of the Thanet Sand in that area. We find that the London Clay is present in force, that the so-called "Oldhaven and Blackheath" beds are missing, whilst the mottled clay is exceedingly well developed.

Mr. Gardner's masterly researches in the Lower Eocenes of the Isle of Mull have been so recently recorded at the Geological Society that his paper is not yet issued to the public.† It would be superfluous for me to mention more than that he has demonstrated, from a careful study of the fossil plants imbedded between sheets of basalt, &c., in that island, that Eocene beds are present, and that some of them, indeed, are older than the Thanet beds of the London basin. This is by far the most important addition to our knowledge of this period which has been made in recent years.

The same observer has also shown that Lower Eocene beds exist in Antrim, in north-east Ireland; and I would refer to his memoirs "On the Age of the Basalts of the North-east Atlantic" ('Proc. Belfast Nat. Field Club,' Ser. ii, Vol. ii, Part IV, 1883-4); "On the Evidence of Fossil Plants regarding the Age of the Tertiary Basalts of the North-east Atlantic" ('Proc. Roy. Soc.,' No. 235, Dec. 18, 1884); and on "The Lower Eocene Plant-beds of the

---

* The possibility of this being the case was, I find, suggested by Prof. Prestwich, 'Q. J. G. S.,' Vol. x (1854), p. 130.

† Since published, 'Q. J. G. S.,' Vol. xliii, Part II, May, 1887.

Basaltic formation of Ulster" ('Q. J. G. S.,' Vol. xli, 1885, p. 82) for further details. The beds are chiefly of the age of the Heersien beds of Belgium, which, as I have elsewhere attempted to show,* are of the same age as the lower part of our Thanet beds. We may look forward with interest to the further investigation of these Irish and Scotch Eocenes.

ORDINARY MEETING.

FRIDAY, APRIL 1ST, 1887.

F. W. RUDLER, F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association :—

Captain W. Ashby; A. Cates; J. W. Dale; H. G. Erith; Rev. E. Hill, M.A., F.G.S.; H. E. Jones; H. W. Sich.

The following paper was then read :—

'On the metamorphosis of basic igneous rocks.' By J. J. H. Teall, M.A., F.G.S.

The paper was illustrated by lantern slides (many of which were photographs taken by Mr. Barrow) and by hand specimens.

THE METAMORPHOSIS OF BASIC IGNEOUS ROCKS.

BY J. J. HARRIS TEALL, M.A., F.G.S.

An igneous rock may be said to attain individuality at the time of final consolidation. Many minerals which enter into its composition may have been formed previously, but the birth-time, so to speak, of the rock is the time when the last portions of molten matter solidify. So long as the rock remains subject to the conditions which prevailed at the moment of final consolidation, it is in a state of stable equilibrium. These conditions do not, however, remain constant, as a rule, for any considerable length of time, and accordingly we find that the rock in adapting itself to the changed conditions, or, in other words, in adapting itself to its environment, undergoes important modifications in structure and composition. As we examine it, the rock is not in its original condition; it has been more or less metamorphosed.

---

* 'Geol. Mag.,' Dec. 3, Vol. iv (1887), p. 108.

The principal mineralogical constituents of the basic igneous rocks are certain anhydrous silicates of complex composition. When subjected to the low temperatures and pressures which prevail at the surface, and to the chemical action of air, water, and carbonic acid, these silicates are in a state of unstable equilibrium, Their molecular structure breaks down, and the chemical elements rearrange themselves, in accordance with the new set of chemical affinities, so as to form compounds which are more stable under the existing circumstances. In this way, silica in various forms, carbonates, iron ores, and various hydrated silicates, such as kaolin, chlorite, and serpentine, are produced. The extent to which a basic igneous rock may be modified by these agencies—the surface agencies as they may be conveniently called—varies within wide limits. It may be so slight as not to interfere seriously with the individuality of the rock, or it may be so great as to completely destroy this individuality. The soluble constituents may be so removed that a pulverulent mass, mainly composed of hydrated silicate of alumina, alone remains to attest the former presence of the igneous rock ; or, under suitable conditions, even this may be carried away mechanically, and the solid rock may disappear.

The metamorphosis of basic igneous by surface agencies has long been so well understood that it is no part of my purpose to treat it at any length in this communication. Another and a very different type of metamorphosis is that dependent upon actions which take place beneath the surface. This is much more difficult to study because the operations go on out of sight, and our information with regard to them is therefore mainly derived from an examination of the effects long after they have been produced. Two different kinds of metamorphism dependent upon actions going on beneath the surface are at present recognized : the principal agent in the one case is an elevated temperature acting under what may be called normal conditions of pressure, that is, under such pressure as is naturally due to the weight of the overlying material ; the principal agent in the other case is the mechanical energy which results in the folding, crumpling, and faulting of the rocks. The effects of these two more or less distinct kinds of metamorphism are often superposed. What is generally known as contact metamorphism may be mentioned as an illustration of the first kind. Messrs. Allport* and Phillips† have familiarized us with the effects of the intrusion of masses of granite upon igneous rocks of basic composition. They have shown that the augite becomes replaced by secondary hornblende, which usually takes the form of uralite or actinolite; that the felspar also undergoes modification; that a pale brown mica is very frequently developed; and that, occasionally, such minerals as axinite, tourmaline, and garnet make their appearance. Lossen has shown that precisely similar results have been produced in the Hartz.

---

* 'Quart. Journ. Geol. Soc.,' Vol. xxxii, p. 407.

† 'Quart. Journ. Geol. Soc.,' Vol. xxxii, p. 155, and Vol. xxxiv, p. 471.

My principal object in this communication, however, is to call attention to the second kind of deep-seated metamorphism, the significance of which we are only beginning to recognize, and most of the details of which yet remain to be worked out. This is generally referred to as dislocation, or regional-metamorphism. It has also been termed pressure-metamorphism, and although certain objections may be taken to this expression, it is a very convenient one to use, and no serious harm will result if we form our ideas as to what is meant by a consideration of the facts rather than by dwelling on what may or may not be indicated by the term itself.

Nothing is better understood by the geologist than the fact that the rocks of the earth's crust have, in certain places, been deformed (strained) by mechanical stresses. We are not agreed at present as to the way in which these stresses have been produced, but, for our present purpose, this is a matter of no consequence. Now, the deformation of a solid mass may take place in two, more or less distinct, ways. It (the solid mass) may crack along certain planes, and the different fragments may slide along these planes. This may be termed deformation by faulting.* Or the deformation may take place by an interstitial movement of the constituents without the formation of actual cracks. This may be termed plastic deformation, or deformation by interstitial movement. A deformation of the latter kind takes place in molten masses erupted at the surface of the earth. Suppose a mass of viscous lava, not entirely homogeneous (say a mass of rhyolite), to be erupted in a boss or lump, and suppose it to be deformed by gravitation into a flat sheet, the resulting mass will show banded and fluxion structures, and the bands will lie approximately parallel to the fixed surfaces which determined the character of the deformation. In the plastic deformation of solid masses precisely similar structures arise.

---

* Good illustrations of this type may be found in almost any district. It is admirably illustrated on a small scale by the faulted slates of the Lake District.

The two types of deformation are not separated by any hard and fast lines. Deformation by faulting may pass into plastic deformation by a diminution in the distances between the different dislocation planes. These may become at last so small as to affect only the individual constituents of the rock. Plastic deformation is, however, usually accompanied by molecular changes; the old minerals are destroyed, and new minerals are formed. In this respect there is a more decided difference between deformation by faulting and deformation by interstitial movement. Nevertheless, it must be remembered that even here the difference is not absolute. Mineral changes often take place along definite planes of movement.

So far, I have endeavoured to sketch in general outline the main features of what may be termed the modern theory of regional metamorphism, a theory which has been mainly developed, in its general aspects, by Lossen,* Heim,† and Lehmann‡. I propose now to apply this theory to the basic igneous rocks, selecting as examples various British rocks which have been examined by myself and others. These rocks are especially useful in determining the structural and mineralogical changes accompanying this type of metamorphism, because we are tolerably familiar with their original structure and composition. Before proceeding to consider the changes in the rocks themselves, it will be necessary to treat briefly of the changes in the different constituents. Regional metamorphism often takes effect on rocks that have been more or less modified by other agencies, so that in dealing with this portion of the subject we shall not limit ourselves entirely to the effects of one type of metamorphism. Indeed, it is very often impossible to separate the effects of different kinds of metamorphism. The essential constituents of basic igneous rocks have already been mentioned. One of the most important accessories is olivine, and we must accordingly add this mineral to our previous list.

PLAGIOCLASE.—The dominant felspar of the basic igneous rocks is labradorite, or bytownite. The synthetic experiments of Messrs. Fouqué and Lévy make it highly probable that the ophitic structure, so common in this group, is dependent on the presence of a basic felspar. These experimenters found that the structure could easily be produced with anorthite and augite, and less easily with labradorite and augite. It has never been produced, so far as I know, with oligoclase and augite.

---

* "Studien an Metamorphen Eruptiv-und Sediment-gesteinen." 'Jahr. k. Preuss. Geol. Landesanstalt für 1883." Berlin. References to numerous earlier papers by the same author will be found in this communication.

† 'Mechanismus der Gebirgsbildung.' Basel, 1878. 2 Bde. and Atlas.

‡ 'Die Entstehung der alt-krystallinischen Schiefer-Gesteine.' Bonn, 1884.

In the granitic rocks of basic composition (*i.e.*, in the gabbros) the felspars give sections having tolerably uniform dimensions in the different directions. In the medium-grained rocks (dolerites) they give lath-shaped sections of considerable dimensions, and in some cases are present also in well-formed porphyritic crystals. In the fine-grained and compact rocks (basalts) they often sink to microlitic dimensions. They almost always show twinning on the albite plan, and less frequently twinning on the pericline and Carlsbad plans. As it is difficult to trace the various stages of metamorphism in the fine-grained and compact rocks, we shall not refer to them at any length in what follows.

The felspars of the gabbros in regional-metamorphic areas present features not known in the corresponding rocks of undisturbed districts. In both, we may find evidence of strain as shown by undulose extinction, and the bending of twin lamellæ, but this is much more marked in the disturbed than in the undisturbed areas. A feature which, so far as we know at present, is limited to the gabbros of disturbed areas, is the partial or complete replacement of the original felspar by a water-clear mosaic of small grains, for the most part devoid of twin striation. The connection between the development of the mosaic and the straining of the original mineral is admirably illustrated in some of the Lizard gabbros. A plane of strain, where it crosses the felspar crystal, is often marked out by a narrow band in which the mosaic structure has been developed. The other parts of the crystal may exhibit merely a bending of the lamellæ. From such a case we may pass by a regular gradation to others, in which the original grain has been entirely replaced by a felspar mosaic.* Cases of the replacement of the original plagioclase of the dolerites, or diabases, by a similar mosaic have been described by Lossen. An important question arises as to the nature of the water-clear secondary felspar. According to Lossen it is in many cases albite. Now, the development of albite at the expense of labradorite involves the separation of lime. This is probably in some cases removed altogether. In others, it remains behind as calcite, or in such minerals as zoisite and epidote. Cathrein's researches on the nature of certain so-called saussurites became of great importance in this connection. This observer proved that many saussurites are mixtures of albite and zoisite. A similar aggregate occurs at Sango Bay, near Durness. I am indebted to Prof. Lapworth for the loan of some very fine examples of zoisite-bearing amphibolite from Ben Hutig in Sutherlandshire. It must not be supposed, however, that all substances to which the term saussurite is applied possess the same composition. Thus the so-called saussurite of the Lizard is often composed of felspar, malacolite, an unknown substance, which is white by reflected, and brown by transmitted light, and minute granules of sphene.

---

* The formation of a mosaic in connection with regional metamorphism appears to be a very common feature. It may be seen in the quartz and felspar of the intermediate and acid rocks.

Mr. Adams* has shown that the felspars of certain actinolitic schists occurring in the Quebec group are rich in soda, and therefore in all probability albite. We must not, however, regard it as proved that the secondary felspar is in all cases albite. Veins of andesine occur in the Scourie dyke,† and there is no reason why the same mineral should not have been developed in the rocks. The balance of evidence at present appears to be in favour of the view that the secondary felspar is in general more acid than the original felspar.

Doubt may exist in the minds of some as to whether a secondary felspar is really developed in connection with the metamorphosis of basic igneous rocks. On this point the evidence seems to me satisfactory. In many cases it is quite easy to distinguish between the two felspars. Thus in the Scourie dyke the original felspar is somewhat turbid. It gives lath-shaped sections, and is entirely free from all inclusions of the ferro-magnesian constituents. The secondary felspar is water-clear. It occurs in irregular grains, and frequently contains inclusions of hornblende.

PYROXENE.—The monoclinic pyroxene of the gabbros is usually diallage; that of the dolerites, augite. Both forms disappear in the process of metamorphism, and their places are taken by hornblende. The secondary hornblende may be uralitic, actinolitic, or "compact." It is said to be uralitic when it is fibrous, and retains more or less of the form of the original mineral. Sections of uralitic hornblende give fairly uniform but not perfectly definite extinction. The absence of definiteness in the extinction is, of course, due to the fact that the axes of the fibres are not rigidly parallel. The hornblende is said to be actinolitic when it occurs in the form of long needle-like prisms, having definite crystalline outline in the prismatic zone. In the hornblendic gabbros or gabbro-diorites, a fringe of actinolite may often be seen surrounding a mass of uralite. Actinolitic hornblende frequently occurs as inclusions in the water-clear secondary felspar. When the hornblende consists of grains or crystals having perfectly definite cleavage and uniform optic characters, it is said to be "compact." Secondary hornblende of all kinds is usually green. Brown tints may, however, be occasionally observed.

---

* 'Report of Canadian Geol. Survey for 1882.'

† 'Quart. Journ. Geol. Soc.,' Vol. xli, 1885, p. 133.

What relation does the secondary hornblende bear to the original augite, so far as chemical composition is concerned? This is a question we are unfortunately unable to answer with any degree of definiteness. We know from the researches of Gustave Rose, Fouqué and Lévy, and others, that augite will crystallize out of a fused mass of hornblende, but this, of course, does not necessarily prove that the two minerals are identical in composition.

We want a series of analyses of the original augite and the secondary hornblende from several different rocks. In considering the relations of the two minerals, it is of the utmost importance to remember, as Mr. Williams* points out, that hornblende is much more stable at low temperatures and pressures than augite. Augite is eminently characteristic of true igneous products; hornblende, and especially green hornblende, is more characteristic of the crystalline schists.† Augite has frequently been produced synthetically; hornblende has never been so produced.

Augite and hornblende develop chloritic products when subjected to alteration by surface agencies. Rhombic pyroxenes occur in some of the basic igneous rocks, and Mr. Williams has shown that they give rise to hornblende very much in the same way as augite or diallage. Surface alteration produces bastite and ultimately serpentine.

OLIVINE.—This mineral may or may not occur. Where it does occur it appears, as Prof. Bonney long ago pointed out, to give rise to hornblende. When affected by percolating waters, it produces serpentine, and the change is often accompanied by the separation of iron oxides. The olivines of gabbros are sometimes surrounded by zones of other minerals, such as enstatite, anthopyllite, and actinolite. Prof. Rosenbusch* holds that zones of anthophyllite and actinolite, such as occur round the olivines of the gabbros of Rosswein and the Lizard, are developed in connection with pressure metamorphism. Mr. Adams† holds that the zones of pyroxene and actinolite, which surround the olivines in certain gabbros of the Saguenay river in Canada, are original. Mr. Williams‡ is of the same opinion as regards the rocks of the Cortlandt series.

---

* "On the Paramorphosis of Pyroxene to Hornblende in Rocks." 'Amer. Journ. Sci.,' Vol. xxviii, p. 259.

† Augite occurs abundantly in certain portions of the Hebridean gneissic system, in association with plagioclase and quartz. The rocks in question may be termed augite or diallage-gneisses. They are the gneissic equivalents of the quartz-gabbros or augite-diorites.

TITANIFEROUS IRON ORES.—These minerals are eminently characteristic of the dolerites. They are of great interest in connection with metamorphism, because their presence will frequently give a clue to the origin of a foliated rock in which almost all traces of the original structure and composition have disappeared. In one special type of dolerite or diabase, very commonly found associated with the palæozoic rocks of the West of England, Wales, and Ireland, the iron ores take the form of plates of ilmenite, arranged in parallel rows, and intersecting at angles of 60°. Sometimes the spaces between the different plates are filled up, possibly with magnetite, and then the reticulate structure can only be recognized after a certain amount of alteration has taken place, or by etching the slide with acid. The characteristic alteration product of ilmenite and titaniferous magnetite is leucoxene, a substance which has been proved by Cathrein to possess the composition of sphene. In some cases the leucoxene of the diabases is partially transparent, and when this is the case it possesses the refraction and double refraction of sphene.

When a diabase with ilmenite is subjected to plastic deformation, the ilmenite often retains its character better than either the felspar or augite. Many of the "schistose greenstones" of Cornwall may be thus shown to be metamorphosed diabases, although the original augite and felspar have entirely disappeared. Plastic deformation does, however, in the end affect the ilmenite. The ragged plates and skeletons become dragged out in the plane of schistosity, and more or less replaced by minute vividly polarizing granules of sphene. In the end the ilmenite disappears, and its presence is then only indicated by long streams of sphene granules.

---

* 'Mikroskopische Physiographie,' &c. 2nd edition, p. 413.

† 'American Naturalist,' 1885, p. 1087.

‡ 'Amer. Journ. Science,' Vol. xxxi, p. 35.

Many hornblende-schists contain rutile, and it is quite possible that this mineral may owe its origin to the separation of titanic acid in connection with the metamorphosis of iron ores.

Having passed in review the more important mineralogical constituents we proceed to consider the rocks themselves. Many observers have held the view that hornblende-schists are metamorphosed igneous rocks. One of the earliest of these appears to have been the late Prof. Jukes. Mr. Allport in his classic paper on "The Metamorphic Rocks surrounding the Land's End mass of granite," suggests that "hornblende-schists may be metamorphosed igneous rocks, some being derived from dolerites or gabbros, while others are very probably foliated diorites." Mr. John Arthur Phillips, whose loss we so deeply deplore, not only realized that a foliated schist might be produced by the metamorphosis of a massive rock, but also clearly indicated the manner in which the change is brought about. He states that on St. Cleer Down "the hornblende slates graduate imperceptibly from crystalline dolerite on the one hand, into clay slates on the other; and instances are by no means wanting where a rock is massive and crystalline near the centre of its outcrop, while externally it is schistose and without visible crystals." He attributes the development of the schistose structure to the cause which produced the slaty clearage in the sedimentary beds. Precisely similar conclusions were arrived at by Lossen from his study of the rocks of the Hartz.

The more recent work of Reusch in the Bergen peninsula,* of Lehmann in the granulitic region of Saxony, and of Lapworth and the Geological Survey in the Highlands of Scotland, have brought strongly into prominence the immense importance of mechanical deformation in relation to the problem of the origin of the crystalline schists. Extensive districts composed of diverse rocks have been so profoundly modified by the earth-stresses that their original structural planes have almost entirely disappeared, and new structural planes have been produced which stand in direct relation to the earth movements. This change has sometimes been accompanied by a crushing, and sometimes by a molecular rearrangement of the original constituents. We will now see how these ideas help us to understand certain facts with regard to basic igneous rocks.

Consider first of all the holocrystalline rocks of medium grain —the dolerites of Mr. Allport, the diabases of continental authors.

---

* 'Die fossilien fuhrenden krystallinischen Schiefer von Bergen.' Leipzig. 1883.

These rocks are essentially composed of a basic plagioclase, augite and magnetite or ilmenite. One very common type of structure is the ophitic. This structure depends on the fact that the augite crystallized after the felspar; augite therefore plays the *rôle* of ground mass. The ophitic structure occurs in rocks of all ages, and has been reproduced artificially by Messrs. Fouqué and Lévy. It is a characteristic igneous structure. Now when we find, in regions which give independent evidence of having been subjected to dislocation-metamorphism, and in these regions alone, that ophitic dolerites pass over into hornblendic and chloritic schists, we are, it seems to me, justified in concluding that the schists in question are due to the metamorphosis of the dolerites. Let us consider illustrations of this.

The Hebridean gneissic system of Sutherland is cut by basic dykes of plagioclase-augite rock. Their general trend is N.W. and S.E. One of these dykes near the village of Scourie passes over in places into a typical hornblende schist. There is no marked difference in chemical composition between the schist and the original rock. The original rock is composed essentially of plagioclase, augite, and magnetite or ilmenite. The plagioclase is generally more or less turbid in consequence of alteration. It is twinned in the usual way, and gives lath-shaped sections. The augite is pale in colour, and, as a rule, without definite form. It is often penetrated by the felspar, and has in such cases crystallized after that mineral. In some cases the augite contains one or more planes of inclusions, and when this is the case it must be termed diallage or pseudo-hypersthene. These inclusions are of some importance, because they may occasionally be seen in the secondary hornblende. The iron ores are present in the form of irregular grains or skeletons made up of plates intersecting at angles of 60°. Apatite occurs sparingly.

This rock has in some places undergone complete or nearly complete molecular rearrangement without the development of foliation; in other cases a most perfect foliation has been produced. The gradual replacement of the pale augite or diallage by green hornblende is admirably illustrated. Sometimes the augite is merely fringed with hornblende, at other times only a ragged core of augite is preserved, at others no augite remains. The hornblende may be fibrous, actinolitic, or compact. Very often it is completely honeycombed, as it were, by little granules of a colourless mineral which is presumably quartz.

This feature is described by Williams in his communication on the Baltimore gabbros,* and is well illustrated in one of his figures. The replacement of augite by hornblende is accompanied by modifications in the felspar. The original felspars became replaced by an aggregate of irregular water-clear grains.

Actinolitic hornblende is frequently present in these grains as inclusions, a fact which seems to prove their secondary character. Twinning is much less common in the secondary than in the original felspar. We have no direct evidence as to the nature of this felspar. Veins of andesine, certainly of secondary formation, occur in the dyke at a point where it has been greatly strained, and it is very probable that the same felspar has been generated in the rock-mass. The iron ores in the altered rocks are often associated with minute vividly polarizing granules of sphene.

The molecular changes above referred to are sometimes accompanied by the development of the most perfect foliation. The transition from the massive to the foliated portions is gradual, and may occur in the space of an inch or less. The resulting schist is perfectly typical. In a schist, as in a slate, there are three directions at right angles to each other which should always be noted. There is first the direction normal to the plane of schistosity; there is, secondly, the direction of stretching, as the Germans call it—that is, the direction in the plane of schistosity in which deformed particles are elongated; and, lastly, there is a third direction, also in the plane of schistosity, at right angles to the other two. These three directions correspond to the three axes of the ellipsoid of deformation (the strain ellipsoid) in a slate. In studying schists and slates it is desirable, if possible, to prepare sections at right angles to each of the above directions. In the hornblende schist of the Scourie dyke these directions are indicated by a rude kind of orientation in the hornblende grains, and by the manner in which the ilmenite has been deformed.

The principal constituents of the schist are green hornblende, felspar, iron ores, sphene, and some quartz. The hornblende occurs in the form of irregular grains, which are, as a rule, slightly elongated in the direction of the vertical axis.

The felspar, in the most perfect schist, occurs in the form of colourless grains. In the less perfect schists a certain amount of turbid felspar is usually present. The iron ores occur as elongated lenticles lying in the plane of schistosity. They are usually bordered by minute granules of sphene, and sometimes a long streak of iron ore may be seen to tail off in a row of such granules. Broken prisms of apatite may occasionally be recognized. Quartz occurs, but is by no means easy to distinguish from the water-clear, untwinned, secondary felspar. The most important methods of discrimination are those which depend on the use of convergent light. Quartz is, of course, uniaxial.

---

* 'Bulletin of the U.S. Geol. Survey,' No. 28.

Let us now turn to the West of England. The basic igneous rocks of this district—the so-called greenstones—are of exceptional interest on account of the extent to which they have been metamorphosed by the Post-Carboniferous earth-movements, and by the intrusion of large masses of granite. Devon and Cornwall, together with Brittany, constitute a part of an old chain of highlands which formed a marked feature in the physical geography of northern Europe during Mesozoic times. The Devono-Carboniferous and Pre-Devonian rocks, of which this chain was composed, are concealed at intervals by Mesozoic and Tertiary strata, but wherever they come to the surface, as is the case in the Ardennes, the Eifel, Westphalia, Thuringia, and the Hartz, they present similar palæontological, stratigraphical, and petrographical characteristics. The chain acquired individuality towards the close of the Palæozoic epoch in consequence of the extensive crumpling of the Palæozoic sediments and their associated igneous rocks. The final relief of the intense stresses which produced this crumpling appears to have been afforded by the intrusion of granite at many points along the chain. The basic igneous rocks, associated with the Devonian and Pre-Devonian sediments, are partly intrusive and partly contemporaneous (lavas and tuffs). They present essentially the same characters wherever they occur. The rocks of the Hartz and the Fichtelgebirge are often undistinguishable, either in respect of their original or secondary characters, from those of Devon and Cornwall. For our present purpose it will be convenient to separate the basic igneous rocks of the Lizard district from those of the rest of Cornwall and Devon. The latter are associated with Devono-Carboniferous and lower Palæozoic strata, and they have been metamorphosed in late Carboniferous or Post-Carboniferous times: the former are associated with serpentine and various schists, and the period of their metamorphism has not, as yet, been determined.

We are principally indebted to Messrs. Allport,* Phillips,† Rutley,‡ and Worth,§ for the information we possess as to the petrographical character of the "greenstones" associated with Palæozoic strata. The classification of these rocks is attended with considerable difficulty in consequence of variations in structure and composition in one and the same rock mass.

These greenstones admirably illustrate the impossibility of separating rocks into sharply defined groups. We can describe the rocks, but to give each specimen a name, which shall denote its character, is impossible.

The variations in structure are partly original and partly secondary. The most important secondary structural characters are those which depend on the development of foliation. The passage of a massive into a foliated rock has already been referred to. The variations in composition are also partly original and partly secondary. The most important secondary characters depend upon the development of chlorite or some form of hornblende at the expense of augite, of leucoxene, and ultimately of granular sphene, at the expense of the titaniferous iron ore, and of water-clear secondary felspar and other substances at the expense of the original felspar.

Lavas and tuffs occur in the neighbourhood of Plymouth and Tavistock, in Devon, and of St. Minver and other localities in East Cornwall. They are probably also represented in West Cornwall by many of the so-called hornblende-slates, but the metamorphism in this region has been so intense that it is not safe to speak very confidently on this point. The intrusive rocks belong to the dolerite family of Mr. Allport, and from our point of view these are the most interesting. They have been less affected by surface agencies than the more porous lavas and tuffs, but they have been profoundly modified in certain localities by regional and contact metamorphism. The least altered rocks occur in the eastern portion of the district. The most common type appears to be an ophitic dolerite (diabase), with skeleton crystals of ilmenite. A certain amount of chlorite is usually present. Examples of this type occur at Yealmpton, Rock, Park House, near Dartington, Pollaphant, Catacleuse, near Padstow, south of Anstie's Cove, near Torquay, and at South Pretherwin. Another type, containing deep brown "basaltic" hornblende (original), and a rich brown biotite (not the pale brown biotite so frequently developed near the contact with granite), occurs at several localities in the Plymouth district.

---

* 'Quart. Journ. Geol. Soc.,' Vol. xxxii, p. 407.

† *Ibid*, Vol. xxxii, p. 155, and Vol. xxxiv, p. 471.

‡ "The Eruptive Rocks of Brent Tor," 'Survey Memoir;' also 'Quart. Journ. Geol. Soc.,' Vol. xlii, p. 392.

§ 'Trans. Plymouth Inst.' 1886.

Dolerites of the above type have been profoundly modified by the granitic intrusions. The augite gives place to uralite and actinolite, the felspar breaks up into a mosaic or into an aggregate of irregular and often perfectly colourless grains; the ilmenite becomes replaced by leucoxene, and a pale brown mica is often developed in considerable quantity. Tourmaline, axinite, and garnets sometimes make their appearance.

Where the rocks have been affected by pressure-metamorphism only, somewhat similar mineralogical changes occur. The hornblende is, however, generally paler, and the contact minerals (the mica, tourmaline, garnet, and axinite) are not present. The most striking feature in these regions is, of course, the development of schistosity, in the manner described by Mr. Phillips. In the Land's End district the two kinds of metamorphism have been superposed, and the contact minerals occur in the foliated rocks. It must not, however, be supposed that the foliation was produced at the time of the intrusion of the granite. The relation of the granite veins (*e.g.*, those of Trewavas Head) to the sediments clearly proves that the latter were crumpled and cleaved before the veins were intruded.

In studying the metamorphosis of the dolerites, the ophitic structure, when present, is of the greatest use. It is often preserved after the entire replacement of the augite by fibrous hornblende. Gümbel's term, epidiorite, becomes very useful if we limit it to dolerites in which the augite has been entirely replaced by hornblende. When the change has been accomplished without the obliteration of the ophitic structure, the rock may be termed an ophitic epidiorite. Now, the passage of ophitic dolerites into ophitic epidiorites, and, finally, into foliated hornblendic rocks, may be observed at many points in West Cornwall, as for example, at St. Ives, near Penzance, and east of Marazion. The foliated rocks differ somewhat from the typical hornblende-schists.

Let us now turn to the Lizard district. This district is separated geologically from the rest of Cornwall by a line of disturbance running from Porthalla on the east to Polurrian on the west. We are not able at present to speak positively as to the age of the rocks occurring on the south side of this line, or as to the date of their metamorphism. In the eastern portion of the district, between Porthoustock and Landewednack, innumerable dykes of "greenstone" occur in the gabbro and serpentine. They appear, however, to be entirely absent from the hornblende-schist, a fact (if it be a fact) very difficult to explain, on the assumption that the dykes are of later date than the hornblende-schist.

In the south-western portion of the district, about the Lizard Head, there is a zone of intense mechanical metamorphism, and in this zone we find lenticles and bosses of "greenstone" associated with actinolitic and hornblendic schists, which owe their origin, in part at least, to the metamorphosis of the greenstone. The general strike of the foliation planes in this zone is about N.N.W. and S.S.E., but there is often a considerable amount of local confusion.

The dykes on the eastern coast have been described by Professor Bonney, and to his descriptions I have little to add. In 1877 he arrived at the conclusion that "they were once all dolerites or basalts, and that the hornblende which undoubtedly characterizes many of them is a secondary product, due to metamorphism of the original pyroxenic constituent."* Subsequent research has merely tended to confirm this generalization, at any rate so far as the vast majority of the dykes are concerned.

Macroscopically the rocks are of a dark purplish or greenish colour, and finely crystalline. They frequently contain porphyritic crystals of plagioclase. There is, however, no sharp line between the granular and porphyritic rocks, and specimens of both types may be often obtained from one and the same dyke. When examined with the microscope the rocks may be classed as dolerites, proterobases (rocks in which the augite has been partially replaced by hornblende), and epidiorites (rocks in which the augite has been completely replaced by hornblende). In some instances foliation has been superinduced by the pressure metamorphism which has affected the district. In these cases the different varieties may be described as foliated proterobases, foliated epidiorites, and hornblende-schists.

---

* 'Quart. Journ. Geol. Soc.,' Vol. xxxiii, p. 915.

At Coverack, and immediately to the north, between this village and Manacle Point, there occur dykes which have preserved their original characters to a remarkable extent. The least altered of these are ophitic olivine-dolerites. The augite is often quite unaltered. It is almost colourless, and occurs in fair-sized masses, penetrated in all directions by the lath-shaped plagioclase. In one case distinct indications of a micro-pegmatitic intergrowth of plagioclase and augite were observed in a slide which showed, as a rule, the normal ophitic structure. The olivine shows no trace of serpentinization. It is, however, grey in colour, in consequence of the presence of minute dust-like particles. With a magnifying power of 1,000 diameters some of the largest of these can be seen to be of a dark reddish-brown colour. In some cases the particles appear to be distributed uniformly through the mineral. In other cases they are aggregated in parallel bands. The olivines are also traversed by irregular cracks, along which magnetite has been formed. The lath-shaped plagioclase is colourless, brown, or turbid. These conditions merely represent different stages of alteration, and may be observed in one and the same individual. Turbid plagioclase forms only a very small portion of the entire mass. As a rule the mineral is as fresh as in any of the Tertiary dolerites. Irregular grains and crystals of magnetite are scattered through the slides, and they are very often associated with a brown, nearly uniaxial, biotite. One or two dykes have been observed in which biotite plays an important part (mica-dolerites or diabases); as a rule, however, it is quite unimportant. It is interesting to note that the iron ore does not occur in the form of large skeleton rhombohedra. In this respect and in the presence of the dusty olivines these rocks differ from the ophitic dolerites of Devon and East Cornwall. They appear, however, to be in every respect similar to the "Ottfjäll-Diabas" of Törnebohm.* In the majority of cases the dykes in the eastern portion of the Lizard peninsula differ from the above in having the augite, and, probably, also the olivine, replaced by secondary hornblende. They are, in short, epidiorites.

The plagioclase may be either turbid or water-clear, and the hornblende may be uralitic, actinolitic, or compact. In a large number of cases the structure of the epidiorites is distinctly ophitic; the lath-shaped felspars retain their outlines and penetrate irregular masses of uralitic hornblende, which correspond in form to the original ophitic augite. Iron ores occur in the epidiorites exactly in the same way as they do in dolerites. The secondary hornblende is generally pale green; pale-brown varieties may, however, be occasionally observed. That the epidiorite and dolerite dykes are of the same age is proved by the similarity in their mode of occurrence, and by the fact that transitions may occasionally be observed from one rock to the other in the same dyke. The uralitization or amphibolization of the augite appears to be accompanied by the development of hornblende at the expense of the olivine. In some of the dolerites the olivines may be seen to be surrounded by a narrow zone of a greenish mineral, which possesses the double-refraction of hornblende, and may probably be referred to this mineral.

---

* 'Neues Jahrbuch,' 1887, p. 272.

Foliation has not been extensively developed in the dykes under consideration, but it occurs occasionally as we have already mentioned. It is often of the flaser-type, but we sometimes find the more even foliation characteristic of the hornblende-schists. Prof. Bonney calls attention to a remarkable instance of the latter. It is found in a dyke occurring at the southern angle of the small beach in Caerleon Cove, about a stone's throw from the Poltesco Serpentine Works. Thus he says :—" It is from four to five feet wide ; the sides for about six or ten inches are very dark and compact, and so platy in structure as to be almost undistinguishable from some specimens of the hornblende schists. This structure is lost rather suddenly, and the rock assumes the ordinary aspect of an igneous rock, consisting of a finely crystalline mixture of white felspar and dark hornblende, with porphyritic crystals of the former as much as ¼ inch long." Under the microscope the ground mass of the central portions of this dyke consist of pale green or brown hornblende, mostly fibrous (uralitic), felspar, either turbid or water-clear, and scattered grains of magnetite. The porphyritic felspars are turbid and have lost their individual action on polarized light. The rock from the margin of the dyke is principally composed of irregular grains of water-clear felspar, green hornblende, and magnetite. A little turbid felspar, giving lath-shaped sections, is present in some slides and absent in others. The micro-structure of the rock so far as it consists of water-clear felspar, compact hornblende, and magnetite is that of a crystalline schist; not that of an igneous rock. It

›sely resembles that of the schist from the margin of the ourie dyke.* Apart from the direct evidence furnished by the ld relations, the occurrence of turbid, lath-shaped felspars would re a clue as to the origin of the metamorphosed rock.

The south-western portion of the Lizard district is, as we have ready stated, a region of intense mechanical metamorphism. The ructural characters of the rocks are similar in many respects to ose which may be observed along the great line of disturbance the north-west of Scotland. One type of rock very common in is highly metamorphic region is a green actinolitic or hornblende hist, and in association with this schist we find lenticles and bosses epidiorite, often distinctly porphyritic and having the forms of e original porphyritic crystals (felspars) well defined. These asses of rock, undoubtedly of igneous origin, never, so far as I ıow, take the form of dykes cutting through the schists, but are cluded in, and sometimes pass over by regular transition into, the hists of similar composition with which they are associated. The iginal relations of these masses of "greenstone" or epidiorite to e surrounding rocks have therefore been to a very great extent stroyed, and both the greenstones themselves and the surunding rocks so completely metamorphosed that it is often ıpossible to determine their original characters in the present state our knowledge.

The most easily recognizable igneous rock in this district is now porphyritic epidiorite. Originally we suppose it to have been a ›rphyritic dolerite. The porphyritic crystals of felspar are presented by white pseudomorphs, sometimes half-an-inch in ngth, the forms of the originals being perfectly preserved. These ystals are somewhat tabular in consequence of the conspicuous evelopment of the brachypinacoid (010); the basal plane (001) ıd the prism faces (110 and $1\bar{1}0$) may also be recognized. In ıort, the crystals, or rather the pseudomorphs, have the forms ıaracteristic of porphyritic dolerites. Under the microscope they re turbid, and rarely show any traces of individual action under olarized light. They lie in a dark green groundmass, which is esolved under the microscope into an aggregate of water-clear lagioclase, uralitic and actinolitic hornblende, and opaque iron ore.

---

* I ought to have mentioned that the schist made out of the marginal ortions of the Scourie dyke is finer in grain than that made out of the entral portions.

The felspar of the groundmass usually shows more or less lath-shaped forms, but sometimes the mosaic structure may be observed. Quartz very probably occurs in association with this plagioclase, but has not been recognized with certainty. In addition to the porphyritic epidiorites above described, we find also non-porphyritic rocks of a similar character.

The lenticles and bosses of definitely recognizable igneous rocks vary in size. They may measure a few inches or a few feet in diameter. They lie, for the most part, perfectly isolated in green actinolitic, hornblendic, or chloritic schists. Sometimes the bounding surfaces are tolerably sharp; at other times the external surfaces of the igneous rock are schistose, and it is impossible to say where the massive rock ends and the schist begins. In studying the development of schistosity, the porphyritic epidiorites are of great interest, because the porphyritic crystals often remain as more or less rounded "eyes" in the actinolitic schist. We will now describe one of these "augen-schists." Examined macroscopically the rock is a green satiny schist, containing small white spots which sometimes show the outlines of felspar, but are, as a rule, more or less lenticular in form. In thin section the groundmass of the rock is seen to consist of long actinolitic needles, water-clear grains of felspar, and grains of leucoxene. The needles are arranged approximately parallel to each other in the plane of schistosity (direction of stretching). Where the streams of needles encounter the white spots (turbid felspar pseudomorphs) they sweep round them in the graceful curves characteristic of fluxion structure. The water-clear substance is certainly in many cases biaxial, and, therefore, may with considerable confidence be referred to felspar. It may be said, in a certain sense, to play the *rôle* of groundmass, for actinolite needles often lie embedded in it. Grains of a nearly opaque substance, in part brown granular sphene, evidently represent the iron ores of the original rock. The "eyes" in the schist are turbid felspar pseudomorphs, similar to those which occur in the porphyritic epidiorites. Their angles have, however, been mostly rounded off. The rocks above referred to are best studied in the neighbourhood of Polpeor, and between that point and Lizard Head.

One conclusion of general interest may be drawn from a study of the metamorphic phenomena of the south-western portion of the Lizard district. We have seen that a clue to the origin of many of the green schists is given by the "eyes" or lenticles which these schists contain. According to the view we have adopted, these "eyes" are portions of the original rock which, for some unknown reason, have escaped metamorphism. Now, if this be correct, it will be found to be of widespread application. "Eyes," or lenticles, of all sizes, ranging from microscopic dimensions to areas occupying many square miles on a geological map, are often found in regions of crystalline schist. It is to these "eyes," or lenticles, and to their relations to the surrounding rocks, that we must look for a solution of many of the problems relating to the origin of the schists.

So far we have been referring only to rocks of the dolerite group. The phenomena of pressure metamorphism are equally well illustrated in rocks belonging to the gabbro group. In his classic work on the origin of the crystalline schists, Dr. Lehmann maintains that the passage of gabbro into hornblende schist in the granulitic region of Saxony is the result of the deformation of masses of gabbro by powerful mechanical stresses. Dr. Hatch* has applied the same theory to account for the phenomena observed in certain rocks from the valley of the Wildshönau. I have ventured to apply the theory to the gabbros of the Lizard. In this district we find every transition from massive gabbro to a typical crystalline schist. The change in structure is always accompanied by a change in the mineralogical composition of the rock. The original rock is essentially composed of labradorite or bytownite and augite or diallage. Olivine occurs in certain varieties. With the development of foliation the original ferro-magnesian minerals disappear, and their place is taken by hornblende; the felspar at the same time passes over into a dense white aggregate—the so-called saussurite. The different varieties of foliated rocks may be designated flaser-gabbro, augen-gabbro, and gabbro-schist. The gabbro-schist is sometimes undistinguishable from certain varieties of the hornblende-schist of the district, but I prefer to call it gabbro-schist, because in the present position of our knowledge we should not be justified in concluding that all the hornblende-schist of the district, or even any considerable part of it, has been made out of gabbro.

In reviewing the whole subject we are naturally led to ask—What light do the facts throw on the origin of extensive masses of crystalline schist? Must we regard all hornblende-schists as the result of regional-metamorphism, operating upon basic igneous rocks? So far as these questions are concerned I will confess at once that I have not made up my mind. I am quite unable to recognize any characters by which we can separate the schists, undoubtedly formed by the metamorphosis of basic igneous rocks, from many of those whose origin is unexplained. If, therefore, we were justified in assuming that all basic hornblende-schists had been formed in the same manner, there would be no doubt in my mind as to the way in which the question should be answered so far as these are concerned. In studying the Lizard schists I have been much struck by their frequent resemblance to metamorphosed gabbros and dolerites, by the general absence over the areas occupied by hornblende-schist of intrusive masses of gabbro and greenstone, and by the occurrence in certain localities, especially near Mullion Cove, of "eyes" or lenticles of coarser grain and less marked foliation than the main mass of the schist. These "eyes" bear the most striking resemblance, both macroscopically and microscopically, to some of the highly metamorphosed gabbros. In no single instance have I ever seen either gabbro or greenstone undoubtedly intrusive in the hornblende-schists of this district.

---

* 'Tschermak's Mitth.,' Vol. vii. (1885), p. 75.

ORDINARY MEETING.

Friday, May 6th, 1887.

F. W. Rudler, Esq., F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association :—

G. F. Blackmore, Assoc. Inst. C.E.; G. H. Carpenter; W. F. Gwinnell, F.R.Met.Soc.; Miss E. Waterman; and J. Wilson.

The following paper was then read :—

'On the unmaking of flints,' by Professor J. W. Judd, F.R.S., Pres.G.S.

Publication of this paper is deferred.

Specimens were exhibited by Prof. Judd in illustration of his paper.

ORDINARY MEETING.

Friday, June 3rd, 1887.

F. W. Rudler, Esq., F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association :—

G. Abbott; E. E. Berry, F.C.S.; J. Berry, M.B., B.Sc., F.R.C.S.; P. C. Mitchell; T. Kingston, jun.; Robert T. Litton, F.G.S., F.Z.S.

The following papers were then read :—

'On the formation of agates,' by Mr. W. J. Abbott; and 'Note on the formation of rounded flint pebbles,' by Mr. J. Logan Lobley, F.G.S.

The latter paper being mainly a criticism on Prof. Judd's paper 'On the unmaking of flints,' its publication is deferred until that paper is printed.

There were exhibited :—

A large series of cut and polished agates, exhibited by Mr. Abbott in illustration of his paper.

Agates from Uruguay, exhibited by Mr. G. F. Blackmore.

Flint pebbles, exhibited by Mr. Lobley in illustration of his paper.

Casts of the hinge of *Perna Mulletii*, from the Atherfield Clay, near Reigate, obtained during the Excursion of the Association on May 21st, and exhibited by Prof. G. S. Boulger.

Rolled flint and quartz pebbles, and concretions coated with siliceous grains, from the Chalk, exhibited by Mr. James Fox.

The Formation of Agates.

By W. J. Lewis Abbott.

When Mr. Woodward appealed for assistance for our Conversazione I responded with an exhibition of specimens of agates, more because I thought them suitable objects for such an occasion than from having made any very special study of them; but constant inquiries have induced me to draw up the following elementary remarks, for which, however, I do not claim much originality.

The term "agate" is of Greek origin, and was originally applied to the parti-coloured varieties of silica found in the river Achates, in Sicily, now known as the Drillo, in the Val de Noto. As soon as a taste for them developed, other localities were found to supply much better varieties, and a consequent decline in their value set in, so that by the time of Pliny they had become quite common. They, however, always retained a certain value, as they formed the chief supply of carnelians, sards, onyxes, &c., upon which were engraved those matchless camei and intaglei, many of which have come down to us at the present day. From an early date agates were imported into Europe from India,* where the agate industry has been carried on for a period stretching back to remote times, many castes being entirely engaged in separate branches of the business; and also from Arabia, which has since pre-historic times supplied large quantities of carnelians. The Arabs to-day collect the subangular pebbles and old arrow heads and make them into necklaces.

---

* Prof. V. Ball's 'Geology of India.'

In Europe the principal seat of the agate industry is to be found in and around Oberstein and Idar,* two little German towns. Its location was directly determined by the geology of the district, for it is here that the eruptive rock known under the name of melaphyre comes to the surface. That in the neighbourhood of Oberstein is surrounded by Permian rocks, and is cut through by the river Nahe and its tributary streams, and also by railway cuttings. Dr. Billing says† the strata can be divided into three series : first, a conglomerate, with water-worn gravel of quartz-porphyry and other trap rocks, united by ferruginous earthy matter and much burned by the second stratum, the trap rock below it, which has forced it out of its level to an inclination of nearly 40°. It also contains veins of chalcedony. Secondly, a dark brown amygdaloidal trap, with an infiltration in some parts of carbonate of lime, varying in colour from brown to olive, more or less porphyritic, passing into greenstone, extends about two miles, with here and there some patches of trap tuff, as far as the village of Idar, where the third kind begins and forms a considerable hill known as Galenberg. This rock is a more basalt-like trap, darker and denser at the lower part of the bed and less so in the upper, which contains the agates.

A magnificent case has lately been arranged at Jermyn Street, showing not only the various types of agate-bearing rocks, but a series of valuable specimens exhibiting the presence of many other minerals in agates, such as very perfect crystals of calcite, apophyllite, chabasite, copper-pyrites, specular iron ore, harmotome, and fluor.

The quiet, sombre aspect of many of our own British agates is due, to a great extent, to their not being artificially coloured. Moreover the action of tropical sun has much to do with altering their colour and imparting a richness of hue. The susceptibility of some layers to take certain colours is very striking, some strata taking some colours readily while apparently quite impervious to others, while some are impervious to any colouring. Our President has been so good as to bring, amongst other things, a beautiful example of five pieces cut from the same stone and dyed differently, the one dyeing exhibiting lines that are not at all apparent in the others. Although the process of "cooking" seems to have been known to the ancients, it was not till a loquacious Roman stone-engraver, in 1819, let out the secret to a fellow-prisoner in Paris, who happened to be an agate-worker of Idar, that it became known in Germany. Almost any colour can be obtained by boiling a stone in a given metallic salt, and subsequently in a reagent which gives the colour precipitate that it is desired for the stone to take. If too deep, colours can be "drawn" with nitric acid. The whites, yellows, reds, and browns are known as *carnelians* and *sards*. If two or more parallel bands occur they give rise to the *onyxes*. If one layer be sard it is known as *sardonyx ;* if composed of variously coloured layers of chalcedony, as *chalcedonyx ;* if a black layer be followed by a white one, as *onyx*. Some varieties known as *oriental onyxes* are very valuable. These have a warm, rich shade of red pervading them, and the white layer is of a complex nature, part highly translucent and part more opaque, with the same subdued, rich tone and tint of red pervading it. In the common onyxes the white layer is generally composed of thickly-set acicular crystals which, if examined separately, would appear transparent, but *en masse* (from their effect upon light) appear quite white.

---

* For the various processes connected with the industry see F. W. Rudler, F.G.S., in 'Popular Science Review,' No. 1, 1877, to which I am greatly indebted, especially for the German references.

† 'The Science of Gems,' A. Billing, M.D., &c., 1867. See also Mr. W. S. Hamilton, 'Quart. Journ. Geol. Soc.,' Vol. iv, p. 209.

Besides the before-mentioned places agates are found in many localities—in Australia, China, Africa, America, Russia, Scotland, and other places too numerous to mention.

In Australia* (and elsewhere) their principal matrix is basalt, notably at Sconce, co. Brisbane ; Kiama, co. Camden ; and the western range of the Dewingbong Mountains, the latter forming the source of most of those found in the old river-gravels of New South Wales. Elsewhere in the Colony the principal rocks occurring at the surface are basaltic and trachytic, and are remarkable for their amygdaloids of chalcedony, agate, arragonite, and zeolites.

In nearly all basaltic districts silicified wood is abundant, much of which was probably overwhelmed by old lava-flows. In most instances it is composed almost exclusively of hydrated silica ; in some with an admixture of alumina, calcium, &c., deposited from solutions. A most remarkable and interesting feature in connection with this subject is, that in many hollows of the wood, agates of various sizes are found, the silica having passed through the delicate pores of the tree in solution, as it did through the more vesicular basalt.

---

* 'The Minerals of New South Wales,' by Archibald Liversidge, F.R.S., pp. 116 and 118.

The possibilities of silica in hot springs can be partly imagined when we recall to our minds the late white and pink terraces of New Zealand, or the picture of the Yellowstone by Dr. Geikie, who, in describing some of the scenery, says :—" A mass of snowy whiteness protrudes from the lateral pine-clad valleys and presents a steep front to the narrow plain at its base . . . looking like a sea of ice. It is all silica, deposited by the hot springs. Near the springs the rocks are in hollows and basins, and as evaporation takes place near the edges there is a tendency to produce these basins. In places where the water trickles over, the sinter looks like frozen waterfalls. The layers of sinter are all highly and variously coloured." This phenomenon of colouration is so remarkable in one case that the geyser is called "the Devil's paint-pot."*

But the formation of agates is not quite so simple and obvious as the formation and deposition of siliceous sinters. The one takes place in open daylight before our eyes, where one can watch every process, step by step ; the other was performed in past ages, far down in the earth, in the secrecy of a cavity or fissure in solid rock, or in the interior of an imbedded tree, into which nothing could penetrate, save potent mineral solutions.

Silica is one of those substances which is known chemically as allotropic, *i.e.*, it is capable of existing in different states. One of these states is known as the *Crystalloid ;* the other as the *Colloid* (sometimes confusedly spoken of as *crystalline* and *amorphous*). If a solution of a crystalloid and a colloid body be put into a vessel having a porous membrane separating it from pure water, the crystalloid body will not only permeate the colloid body, but will pass through the diaphragm into the water, leaving the colloid solution behind, the process being named by Graham "dialysis." If, for example, solutions of sodic or potassic silicates be so dialyzed, the sodium or potassium passes away and leaves the colloid silica behind.† Also if alkaline silica be poured into an acidulated sodic silicate a jelly is formed with a species of cavity, subsequently exhibiting a series of somewhat horizontal bands as shown by Messrs. I'Anson and Pankhurst, who have also shown[*] that hollow stalactites (or what I should prefer to call "stalactettes") may be formed by introducing strong sulphuric acid, by means of a pipette, into the bottom of a vessel containing a strong solution of silica with some alkaline carbonate. As soon as the bubbles of carbon-dioxide arise, silica is deposited by the decomposition of the alkaline silicate, and a tube of silica is formed, which continues to grow as long as the acid flows. The same result can be produced by passing CO_2 through an alkaline silica solution. If the solution be saturated with an acid reagent the whole of it gelatinizes. It is probable that those remarkable masses of gelatinous silica at the bottom of the lakes in the Yellowstone Park[†] are similarly deposited by the CO_2 rising from volcanic sources.

---

* Geikie's 'Geological Sketches at Home and Abroad,' p. 261.

† Jukes and Geikie's 'Manual of Geology,' 3rd ed., p. 47.

It is also well known that when silicate of calcium is acted upon by carbonated waters, carbonate of calcium is deposited and silica set free;[‡] and it is worth while to remember that labradorite—the most prone of all felspars to alteration—is a constituent of the Oberstein melaphyre; and that often, the more altered and decomposed the rocks, the better the agates. Some specimens of the decomposing rock show a regular net-work of chalcedony from one cavity or fissure to another.

The crystalline form of silica is too well known to need a word; but one or two facts must, however, be borne in mind, viz., that crystals[§] can only form when molecules are free to arrange themselves into crystalline forms; that the position of crystals in the cavity influences their relative shapes and the development of their faces; that the apices of singly terminating crystals always point away from their point of origin; that crystals formed in gelatinous matter suffer fewer modifications and are generally well formed; and that (as was also observed by Messrs. I'Anson and Pankhurst and the French synthetical chemists) temperature and pressure also influence the formation of crystals.

Silica is also, mineralogically speaking, polymorphous. The chief varieties, however, that enter into the composition of agates are chalcedony, quartz, jasper, and opal, and, although scarcely two authorities agree in their respective definitions of them, certain features exist that readily distinguish these varieties from one another.

---

[*] "On Some Artificial Forms of Silica, &c.," by J. I'Anson, F.G.S., and E. A. Pankhurst, 'Mineralogical Society's Transactions,' Vol. v, pp. 34-40.

[†] Described by Dr. Hayden.

[‡] See also M. Daubrée, 'Études sur le Metamorphisme.'

[§] Jukes and Geikie's 'Manual of Geology,' 3rd ed., p. 37.

By far the chief constituent of agates is chalcedony.[*] This is described by some as crystalline quartz with varying proportions of aluminium, iron-oxide, water, &c.; by others as true quartz with varying proportions of opal disseminated through it.[†] But as analysis does not support the former definition, and the second is also claimed as a definition of flint, we must fall back upon something more precise. Its stalactitic structure when present will always distinguish it; but, when massive, we must resort to the microscope, which reveals it as essentially reniform in structure. By this I do not mean only that it is sometimes found in more or less kidney-shaped masses; but that it has a radiating form of incipient acicular crystallization at right angles to the plane of deposition, forming mammillated bosses (similar in structure to segments of some stalactites). It often polarizes with a cross of the greatest delicacy and beauty, altogether different in appearance from the hard, brilliantly flaming, but formless, harlequin patches of crystalline quartz. Whether it be stalactitic or be deposited in its characteristic bosses along fissures, or even when there is no sign of superimposition of layers, these radial structures are present, and sometimes meeting each other from neighbouring centres, form polygons, of a more or less symmetrically hexagonal shape, which at times bear no relation to the lines of deposition, and so give the stone quite a facetted appearance. Whenever we find chalcedony anything like pure it has always this tendency to the formation of bosses and circular radiating lines—not, however, to be confounded with the rings in beekite. If chalcedony be deposited in a fissure it is always veined parallel to the sides of the vein, with the same tendency to mammillation, radiating outwards from the point of origin. Sometimes the true crystalline quartz is present in a more or less inseparable mass, but it can readily be detected by the polariscope.

Now in opposition to this radial and circular force in the formation of agates, we have also the rectilinear force of true hexagonal quartz ; and, as might be expected, both are capable of producing features of equal distortion. But the clearness of quartz in agates, and its angularity will generally enable us to identify it; and with the polariscope we immediately miss the acicular fibrous-looking structure, and we get the bright patches of violet, blue, red, or any other colour, changing entirely with the slightest turn, and totally dissimilar to chalcedony.

---

[*] See Prof. T. Rupert Jones, F.R.S., "On Quartz, Chalcedony, Agate," &c., 'Proc. Geol. Ass.,' Vol. iv, p. 443, whose beautiful simile that chalcedony stands to quartz as barley-sugar does to sugar-candy is among the truest and best he ever used.

[†] Dana's 'System of Mineralogy,' p. 194.

Jasper may be readily distinguished by its somewhat dull, earthy fracture ; by its almost complete opacity; by its sometimes assuming a somewhat pisolitic structure, and by its generally containing more or less impurity. Jaspers are often clay-slates, sandstones, &c., metamorphosed. Sometimes whole beds become charged with silica and converted into jasper as those from Haldon Hill, India, and elsewhere. Jaspers, flints, and other varieties of silica are often very porous and susceptible to subsequent colouration from without, and to decomposition, giving rise to the so-called Egyptian agates, those of our east coast and elsewhere; but in these it will be seen that the lines are simply colour lines, or zones of decomposition, accompanied by no change of substance or structure, beyond that which we should expect to find under such conditions, and no arrangement of crystals and mammillations such as those above described.

Opal can be readily distinguished by its superior lustre and characteristic fracture; by sometimes exhibiting prismatic colours (owing to its microscopic cavities); when zoned, by being so rectilinearly and transversely to the vein* in which it is often bedded; and by several negative characters, the iridescent variety being never reniform or pisolitic. It is known to be deposited from hot springs in fissures, as in many parts of Australia, Iceland, the Faroës, &c., where it sometimes passes off into siliceous sinter.

From the simplicity of the foregoing explanations one would imagine that no one would contest them. Such, however, is not the case, for there is scarcely a fact which I have submitted, or an assertion that I have made, that is not opposed by someone. The very cavities in the rocks are regarded by some as representing spaces once occupied by some porphyritic crystals since removed, the angles of which have been subsequently removed by the solvent action of acids.* But, as you are aware, the action of an acid would be to fret away and pit out rather than to leave the cavities as we find them, to say nothing of what has become of the new products of the operation. A glance at one of the specimens on the table, however, clearly shows the rock to have at one time flowed, the cavities (which were caused by the escape of gas and steam when the body of the mass was sufficiently tough not to collapse) being drawn out in the direction of the current. In the cuttings along the roadside about Oberstein and Idar you may see the countless little almond-shaped cavities, some hollow, but mostly charged with chalcedony, although calcite, apophyllite, and other minerals before-mentioned are sometimes present. They are, at times, so thickly set that some have indeed regarded them as a conglomerate, and the enclosing rock as the cement. There is one feature about these cavities that I should like to point out, and that is the bursting of small bubbles into large ones, and the consequent production of small bosses pointing inwards towards the centre. Now wherever we find this structure we may be sure that the rock has been in a plastic vesicular condition, and that, after hardening, a model of the inside of one of these cavities would show itself covered with corresponding concavities. Now this is exactly the configuration presented by the oûter chalcedonic layer of agates, clearly showing that the agate was deposited after the cavity had assumed its present form. Moreover, we have noticed that the characteristic mammillæ of chalcedony always point from their origin, so that a section of an agate immediately reveals whether it was formed from a centre outwards or the reverse. Nevertheless, Prof. Ruskin has come to the conclusion that "the bands of agates, even when most distinct, are not successive coats, but pisolitic concretions of amorphous (?) silica," and that "it is not a case of deposition at all, but of chemical segregation." As might be expected, a theory like this does not stop here, and he goes on to deal with what we call conglomerates, such as the Hertfordshire conglomerates, which he says "is not a conglomerate at all, but dissolutions of concretionary rocks."† But the matrices of this conglomerate vary from friable iron-sand to a silica as hard as the pebbles themselves. The pebbles are covered with the minute conchoidal pittings sustained during the process of being water-worn, and often contain fossils of such shape that the part of them that reached the edge of the pebble has been worn off; and, further, in such conglomerates there are various degrees of angularity present until we reach breccias in which the constituent pieces often exhibit conchoidal fractures on their surfaces; or in others we have pebbles of various well-known formations present.

---

* *i.e.*, so far as the specimens I have seen go. See also the valuable and highly suggestive papers of Mr. Ruskin "On Banded and Brecciated Concretions," 'Geol. Mag.,' 1867 to 1870, to which references might often be made in various parts of this paper ; but the whole articles are so full of information and original observation that they ought to be read by everyone.

---

* Bischof, 'Lehrbuch d. Chem. u. Phys. Geol.,' 1866, Vol. iii.

† See 'Geol. Mag,' *loc. cit.*

Having thus glanced at the various constituents of agates, their modes of deposition and the features they exhibit, we will next pass to the features presented by the agates themselves and a few of the theories put forth to account for their origin; and, before doing this, let me warn you against theorizing upon features presented by a single section accidentally cut. When we remember the irregular shape of these geodes, or, indeed, of any zoned structure, it is evident that we can make as many varieties as we like, or find coincident lines in things most dissimilar, such as slag, agates, gall-stones, and clay-ironstone opal matrix. This has led Dr. George Harley, F.R.S., to claim an identity of origin for all concretions, whether animal, vegetable, or mineral, irrespective of their mode of formation or locality of deposition.*

All agates that I have seen (that is some tens of thousands) can be divided into three great groups, presenting the general structures of—

I.—Successive deposition.

II.—Chemical precipitation.

III.—Faults, subsequent deposition and brecciation, combined with either, or both, of the other two.

I.—Successive deposits. These may be (A) stalactitic, formed from the centre outwards, *exogenous;* (B) formed from without inwards, *endogenous;* or (C) of both, *compound.* Which of these they are, will become obvious on inspection, when we remember what has been said of deposition of the various forms of silica. The greatest peculiarity of agates, however, lies in the fact that all the layers are not in the same form of silica. They may be composed of (*a*) all chalcedony; (*b*) chalcedony and some variety of rock-crystal; (*c*) chalcedony, rock-crystal, and jasper; (*d*) chalcedony and jasper; (*e*) jasper and rock-crystal. The layers thin out towards certain points, somehow leaving the innermost layer in connection with the outer world. In some sections that I have cut through matrix and agate, the connection immediately underlies one of those small burst bubbles of which I have spoken, in others, it forms quite a boss; but, be that as it may, the one thing that appears necessary to the formation of a solid agate of this group is that the innermost layer should be connected with the outside. As soon as this connection is severed supply ceases, and we get a hollow. Sometimes, from the irregularity of outline, part or parts of the agate get cut off, leaving a cavity or cavities, which are sometimes found to contain a large quantity of water. Generally the last layer (under such conditions) is in the crystalline state. It is thus suggested that the silica was brought into the chamber by the ordinary process of infiltration, the saturated solution being brought in through this aperture;* whilst doubtless a circulation was kept up outside the agate; for, as deposition was effected, a current would be set up to establish equilibrity between the solutions in, and outside the cavity. The sweep of this current is often very distinct, sometimes sweeping from one aperture to the other without rising above them; and it can be exactly imitated artificially. It is thus probable that some apertures served as outlets. Although these apertures, as seen in section, suggest the idea of being round, they were often in the form of irregular cracks.

---

* British Association, 1886. Unfortunately this paper was not published. The learned doctor, to me, has always held the volcanic origin of agates. In the discussion which followed this paper, however, he conceded that he was prepared to admit that all were not of volcanic origin.

Herr Lange, of Idar, objects to this theory, and suggests † that, after gelatinous silica had been deposited on the floor of the cavity, an accession of temperature caused the water to boil, that the pressure of the steam forced the jelly in all directions, and that, if the tension became too great, it pierced an exit. Hence he calls these apertures of infiltration, *irruptive canals.* But thin-walled geodes in a very vesicular rock nearly full of water in no way favour this idea; and further, microscopic sections cut through agate and matrix show relations a great deal closer than mechanical pressure, chemical action being often visible all round. The green layer of delessite, so long regarded as the first deposit, or covering, is shown not to be of local deposit, but the result of general percolation. Moreover, when once the aperture was formed and the water sent out, innumerable other boilings would be necessary. Nor do experiments by forcing more gelatinous liquids into the centre of a punctured cavity already charged with coloured clays resemble the structures generally presented by agates. Haidinger, on the other hand, suggested that there has been no aperture of infiltration, but a general exudation through the whole walls. Dana says "it is more probable that the silica passed through the outer layers by osmosis."* To this I would answer, that although some layers of agates are permeable, as evinced in "cooking," others are absolutely impermeable, and I do not see how colloid silica could pass through such a diaphragm. Dr. Sullivan says they are due to the dialysis of solutions of silicates, the crystalloid bases going away through the porous stone.†

---

* As held by Prof. Nöggerath, of Bonn.

† 'Die Halbedelsteine aus der Familie der Quarze,' 1868, p. 17.

Another variety of feature presented by this group of agates is that, although the layers when rather thin are deposited very evenly over the whole of the agate, when they are thick there is often a tendency to thicken out very much along descending and lower parts, and for some layers to be deposited only in horizontal bands along the floor of the cavity. I use the terms "floor" and "horizontal," firstly, because when pendant stalactites are present they are always at right angles to these bands; secondly, because assuming them to be the result of gravitation the structures they present, such as the parallelism of bands in adjacent agates of different shapes and at different altitudes in the rock, support the conclusion.‡ Of these bedded agates we have three varieties —

A.—True "lake"—showing a total disregard for the shape of the cavity, filling the lower parts first, and always in bands presumably at right angles to gravitation.

B.—Alternation of both states at different periods.

C.—Mixture of true and apparent lake, consequent upon the ordinary (endogenous) method of deposit finding a straight line left, which it follows as it does the irregular outline of the other parts of the cavity without the interposition of gravitation.

Bischoff considers that these bedded layers were due to the fluid being introduced rapidly and then allowed to rest at the bottom of the cavity (in contradistinction to the concentric layers, which he considers filled in more slowly, and spread over the entire walls, without accumulating on the floor).* Others consider that the quantity introduced at one time was never large, nor stood high in the cavity. Something in favour of both might be advanced, but it is more probable that in many instances the layers represent the introduction of an acid gas into the cavity containing the solution, precipitating the silica therein contained. Certainly these horizontal bandings are quite inexplicable by any "outlet," "volcanic," or "segregation" theories, as the uppermost band is often in communication with the "aperture of infiltration" and subject to cessation of growth on its being cut off.

---

* 'System of Mineralogy,' 194 and 195.

† Jukes and Geikie, *op. cit.*, p. 60.

‡ I think there is an example of this in Mr. Ruskin's collection of agates, in the Natural History Museum, South Kensington, but when seen *in situ* the thing becomes certain.

II.—Chemical precipitation. (A.)—Those that show a clear unmixed precipitation. This feature can be best recognized by those who have studied either chemical precipitation; the mixing and separation of substances of various densities, colours, and temperatures; or the structures which can be produced by the precipitation of colloid silica. It is in connection with this part of the subject that the experiments of Messrs. I'Anson and Pankhurst become of inestimable value. Sometimes stalactettes are formed in the centre of a cavity with their characteristic hole, and the cavity is subsequently filled, with the exception of the centre of the stalactette, which is then miscalled an aperture of infiltration. In such a case ex-, or endogenous growth of the centre can be readily determined by remembering that crystals and chalcedonic mammillæ are formed from their bases outwards. Often these small stalactettes, from the size of a small bird's quill, an eighth of an inch long, and only two or three in number, up to half an inch in diameter and two or three inches long, occur closely set in agates, and they were a puzzle to me for years; but in this instance no doubt the cavity contained a solution of colloid or gelatinous silica, and these were formed by the introduction of CO_2 through the various pores in the rock, solidification and subsequent deposition in the usual manner completing the history of the agate. (B.)—The so-called moss agates and their allies. The beautiful red and yellow ferric, and green ferrous oxides of the specimens on the table, now in flocculent masses, now in fantastically-contorted hair-like filaments, together with the peculiar sweeps and turns of colloid, or curiously-mixed silica, is at once suggestive of the ideas of contemporaneity of origin and chemical precipitate. (C.)—Pagodaites and dendrites. These have been formed by subsequent colouring matter introduced by fissures or cracks; the formation of dendritic markings on substances slightly impervious is well known. Potters also resort to it for a cheap form of decoration by dropping wet colour on the article and letting it run, when it assumes a dendritic form. When introduced through a crack at right angles to the bedding, each succeeding layer it passes is of about the same porosity on either side of it, and we consequently get a figure, more or less bilaterally symmetrical, giving the appearance of a pagoda. There is a most extraordinary stone in the Museum of Practical Geology exhibiting a row of spindles and pulleys all arranged in a row! When the colouring matter is introduced through a fissure between the layers we get the same result as the potter—a dendritic marking. If the bands be fairly level, one layer can be cut so as to only leave a small but even thickness over it, and so to exhibit its peculiar beauty. Sometimes, however, the bedding is of an irregular form, and then the stone has to be cleverly cut in order to keep the same thickness of stone over the marking, and so to preserve the dendritic marking of apparently uniform colour.

---

* 'Lehrbuch d. Chem. u. Phys. Geol.,' Vol. iii.

III.—The well-known features of faulting, subsequent infiltration, and brecciation. The phenomenon of faulting is often seen in agates, giving rise to ruin agates, &c., and often in the process a new inlet for silica is opened in the agate, where the old aperture had become choked up and left a vacant cavity in the centre, and a new deposit then follows, sometimes very similar to that already forming the agate, at others very dissimilar from it.

Brecciation is also often present, in which case the agates have been broken into fragments and agglutinated by a chalcedonic or other siliceous paste, sometimes colloid, sometimes crystalloid, and at others quite indistinguishable from the banding in agates, as in those of Ramelsburg, &c. When we remember that we have long been taught that mountain masses flow, can we expect to find no trace of it in these banded structures; or ought we not rather to expect them to register the vicissitudes through which they have passed much better than practically structureless rocks?

Lastly, one word upon the supply of silica. This might have been twofold—from deep-seated thermal springs, which in periods of great activity might deposit silica in the chalcedonic form; or from percolating meteoric waters charged with silica from the decomposing rocks, which being deposited in a slower manner might assume the crystalline form. When we have learned the exact relation between all these various forms and conditions of silica we shall be better able to say, but "now we see through a glass darkly," and faintly discern in the microscope structures in solidifying gelatinous silica, related to those we find in chalcedony; while in chalcedony the polariscope reveals structures struggling, as it were, towards crystallization; and, further, some stalactites in India (and elsewhere) are formed of chalcedony roots imperceptibly passing off into clear crystalline quartz, with crystal faces. The same phenomenon is very often exhibited by agates; and, above all, as chalcedony does not occur as a constituent of any volcanic rock, but—to use the words of Prof. Rupert Jones—"in all cases it seems to have been deposited from water holding silica in solution," we may, I think, fairly claim a similar origin for agates.

ORDINARY MEETING.

FRIDAY, JULY 1ST, 1887.

F. W. RUDLER, Esq., F.G.S., Hon. Sec. Anthrop. Inst., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—

T. Cooper; C. H. Furnival; Rev. W. B. Galloway, M.A.; A. Keay; F. W. Quick; and J. Straker.

The Hon. Secretary, Dr. Foulerton, was then presented with a Petrological Microscope, which had been subscribed for by Members of the Association in recognition of his long and valuable services as Secretary, by Dr. HICKS, supported by Mr. TOPLEY.

Dr. FOULERTON replied in acknowledgment of the presentation.

The following papers were then read :—

'On the geology of Cornwall, with special reference to the Long Excursion,' by Mr. J. H. Collins, F.G.S.; and 'On the deposition of the London Clay,' by Mr. J. Starkie Gardner, F.G.S., &c.

Sketch of the Geology of Central and West Cornwall.

With special reference to the Long Excursion.

By J. H. Collins, F.G.S.

(A Paper read at the Geologists' Association on July 1, 1887.)

Part I.—General Geology.

Introduction.

The stratified rocks of the Central and Western parts of Cornwall—with the exception of about twelve square miles of Lower Silurians on the South Coast, forming the parishes of Gorran, Caerhayes, and Veryan, and a smaller area of much older rocks at the Lizard Point—are represented on the maps of the Geological Survey as Devonian.

It has long been known, however, that the Lower Silurians have a much greater extension to the west and south-west, and that parts of the district—especially near the mines—are much older. Sir Henry De la Beche, in his "Report," speaks of their extension to Mesack Point, some miles up the Falmouth Harbour,* and hints at their being continued into the district to the south of the Helford River,† and this I was able to show in the year 1879 was actually the case, having traced them southward to St. Martin's in Meneage, and westward beyond Helston to the Looe Bar.‡

The Granite.

The geological structure of the district in question is of great interest, and, in its broad outlines, very simple. The fundamental rock is a mass of granite extending from Dartmoor to the Scilly Isles, a distance of about 125 miles. This granite is for the most part overlaid by other rocks of various kinds, but it appears at the surface on the mainland in five large masses and several smaller ones, which form the highest land of the district, rising gradually from hills of about 500 feet high in the extreme west, to others of four times that height in Dartmoor. The granite throughout this large tract of country, with a few merely local exceptions, is essentially the same in mineralogical character; consisting of glassy quartz, generally of a somewhat smoky tint, grey or white felspar, and dark coloured mica. Near the junctions of the granite with the slaty rocks another mineral, known as schorl, or "cockle," is often very abundant. This is a kind of dark-coloured or black tourmaline, very hard, glossy, and brittle. It is frequently associated with tin-ore, with which, indeed, it may very easily be confounded by the inexperienced, although its specific gravity is only about half as great. Its presence is considered a fair indication of tin in granite districts; while in the slate districts a microscopically-developed variety known as "blue-peach" is regarded as a good indication. Fine examples of this may be obtained at Dolcoath, Carn Brea, and other mines near Redruth. Certain notable bands of a granular mixture of this schorl with quartz traverse the granite in many places, but rather as infiltration-veins than as dykes. The best example is that known as Roche Rock; but others may be studied at St. Mewan Beacon, Cregan rocks near Bugle, &c.

---

* 'Report on the Geology of Cornwall,' &c., p. 86.

† *Ibid.*, p. 95.

‡ "On the Geological Structure of the Northern Part of the Meneage Peninsula," 'Trans. Roy. Geol. Soc. Corn.,' Vol. x, p. 47.

Other very important modifications of the granite—more or less complete transformations *in situ*—are the so-called china-stone and china-clay deposits. Those connected with the St. Austell granite mass were very fully described by me in 1878.* They will be briefly noticed in the second part of this paper.

Stratified Rocks.

A kind of clay-slate, locally termed "killas," rests upon the flanks of the granite masses, and partially fills up the hollows between them. This killas is very variable in its appearance and composition in different parts of the district; but generally it seems to be more highly crystalline near the granite than at a distance from it. The junction of the two rocks is well seen at many points upon the coast, and in several of the mines, especially in those lying to the north of Carn Brea Hill, near Camborne. In some places the granite is seen curiously penetrating the slate in the form of veins, as at Wicca Pool, near Zennor, Tremearne, in Breage, and especially on the north-west flank of St. Michael's Mount, near Penzance.

---

* 'The Hensbarrow Granite District: A Geological Description and a Trade History,' by J. H. Collins, F.G.S., Truro, 1878.

The original lines of "bedding" of the slate are not always easily determined, in consequence of the rock being so highly metamorphosed by chemical infiltrations; they are also frequently much obscured by cleavage and jointing. On the whole, however, the slaty rocks appear to rest upon an irregular surface of granite, and to dip mostly away from the great central masses.

In various papers read by myself and my son, Mr. H. F. Collins, A.R.S.M., within the past ten years to the Royal Geological Society of Cornwall, the Royal Institution of Cornwall, and the Geological Society of London, the stratigraphy of Central and West Cornwall has been dealt with in considerable detail. It appears that besides the general mass of killas, probably of Lower Silurian age, there is a large extension of fossiliferous quartzites and limestones of that age, first discovered by the late Mr. C. W. Peach; a series of newer fossiliferous beds largely developed near Fowey, which we believe to be Upper Silurian; and a series of still newer beds containing thick masses of sandstones and quartzite, probably Lower Devonian. In addition, there are extensive beds which are certainly pre-Silurian in the neighbourhood of Ponsanooth; the Archæan beds of the Lizard promontory; the recently-discovered Pliocene patch near St. Erth;* the still more recent sands and gravels of St. Agnes' Beacon, Crousa Down, and many other places; and the now forming blown sands of the north coast.†

As the Association will not visit any of the fossiliferous localities other than that at St. Erth, and their attention will be in the main taken up with the intrusive phenomena and with the economic geology of the county, I need not dwell on the subject of stratigraphy. Those who wish to pursue this part of the subject will find a record of all that has yet been done, together with very full lists of fossils so far as they have yet been determined, in the papers already referred to. ‡

---

* Described by Messrs. Searles V. Wood, junr. ('Quart. Journ. Geol. Soc.,' xli, p. 65), Kendall and Bell (*ibid.*, xlii, p. 201), and Clement Reid (' Nature,' Aug. 12, 1886, p. 342).

† Described by Messrs. Kitto and Davis ('Trans. Roy. Geol. Soc. Corn.,' ix, 196), and W. A. E. Ussher ('Post-Tertiary Geol. of Corn.,' 1879).

‡ 'Trans. Roy. Geol. Soc. Corn.,' x, p. 1, 47, &c. 'Journ. Roy. Inst. Cornwall,' No. 24, p. 18; No. 28, p. 80; No. 29, p. 162.

The numerous "submerged forests" and "raised beaches" which surround the Cornish coast will be outside the scope of the present Excursion. Many of these were described by Sir H. De la Beche; others have been described by Ussher, Whitley, and other local observers. New discoveries in this direction are continually being made. Even within the past month a new "submerged forest" has been laid bare and examined by the members of the Royal Institution of Cornwall.

Intrusive Veins of pre-Granitic Age.

Each of the formations above referred to affords abundant evidence that it has been upheaved, contorted, and extensively denuded away before the deposition of its successor—indeed, it has no doubt furnished a considerable part of the material from which that successor has been formed. With the possible exception, too, of the Fowey beds, each has been subjected to the intrusion of igneous rocks, mostly of a basic character, before the extrusion of the granite. Thus, the Ladock beds and the Lower Silurians are traversed by the remarkable group of "mica-trap" veins, described to the Royal Institution of Cornwall, in 1884, by myself and my son, H. F. Collins.* They cut through the shales and sandstones in a great number of places throughout a band of country extending from Roscreage Beacon, three miles south of the Helford River—in a direction running a little to the N. of east, to Watergate Bay—a distance of nearly 30 miles, the band affected being nowhere more than three miles in width. The individual dykes for the most part course about N.N.E., but they are often somewhat tortuous, and frequently split up into branches, some of which have for short distances very different directions. On the whole, I do not think they can be said to occupy regular fissures, but rather to have been forced between or through the rocks wherever they could find lines of weakness. So far as I am aware, these mica-traps occur in this narrow band of country and nowhere else in England, excepting only in the region to the south of the Lake District of Cumberland. Until very recently, such rocks were altogether unknown in our country, but those of Kendal and Sedbergh were described to the Geological Society by Messrs. Houghton and Bonney in 1878.†

---

* 'Journal,' No. 29.

† 'Quart. Journ. Geol. Soc.,' 137, p. 165, 1878.

Similar rocks occur in Scotland, Ireland, and in several of the Channel Islands, as well as in Normandy and many other parts of the Continent. Other intrusive rocks, known locally as "greenstones" or "irestones," and consisting of variously altered diorites, dolerites, and tuffs, occur pretty generally throughout the district, and have been described by Mr. Allport, Mr. J. A. Phillips, and myself.* Many of these will be met with in the course of the Excursion, especially near Penzance and on the cliffs near Botallack Mine. Not all, however, of the so-called greenstones are intrusive rocks; some are merely altered beds of stratified rocks, and this, I believe, is especially the case near Redruth and Camborne, and largely also at St. Just.

Granitic Intrusions and Later Intrusive Veins.

The situation of the various intrusive masses of granite and its general mineralogical character have been already described. The penetration of the slate by the granite in the form of veins may often be seen where there is a junction laid open, although other junctions are true faults. Some of these veins are very large, and they occasionally enclose fragments of slate not at all differing in appearance from the main mass in the immediate neighbourhood.

The dykes locally known as "Elvans" are very closely connected with the granite, and were undoubtedly formed soon after the main granitic extrusions had taken place. Sometimes, indeed, they are spoken of as "granite veins," but they are quite distinct from these mineralogically and in their mode of connection with the granite.

They consist of quartz-porphyries, felspar-porphyries, and fine-grained felsites; they cut through all the rocks already mentioned indiscriminately; they often occupy distinct fissures and lines of fault; they divide and reunite so as to enclose portions of "country" between their branches, and their main course is that of the principal lodes, with which they have a very intimate connection. A good example of felsitic elvan may be seen in the railway-cutting at Foxhole near Nanpean, while well-marked felspar-porphyries may be seen between Redruth and Camborne, and notably at Tuckingmill.

---

* J. A. Phillips, "Rocks of the Mining District of Cornwall," 'Quart. Journ. Geol. Soc.,' Aug., 1875. S. Allport, "Rocks of Land's End Mass," *ibid.*, Nov., 1876. J. A. Phillips, "So-called Greenstones of West Cornwall," *ibid.*, May, 1876. J. A. Phillips, "So-called Greenstones of Central and East Cornwall," *ibid.*, Aug., 1878. J. H. Collins, "Serpentine of Duporth," 'Mineralogical Magazine,' Vol. i, 1878.

The Archæan rocks of the southern part of the Meneage Peninsula, the Lizard District, have their own system of intrusive rocks, Gabbros and Serpentines, as well as ordinary Dolerites. The age of these intrusions has not yet been determined, but the subsequent intrusions of granitic matter at Kynance and elsewhere may perhaps have been contemporaneous with the similar intrusions in the mining districts.

Conclusion to Part I.

The observations of the past few years show that Central and West Cornwall, excluding the Archæan rocks of the Lizard, the recently-discovered patch of Pliocene at St. Erth, and the various superficial deposits, is composed of four distinct series of stratified rocks, ranging from the Cambrian to the Middle or Upper Devonian periods, each series lying unconformably upon the denuded edges of its predecessor. Speaking generally, it may be said that the rocks met with are older as we go westward.* Furthermore, these various rocks have been traversed by dykes, and intrusive sheets, or overlaid by contemporaneous layers of materials of volcanic origin, and subsequently have been cut through by masses of granitic material, doubtless of more deep-seated origin. As regards these later intrusions, the granite often sends out veins into the adjoining stratified rocks, as may be seen on the shore of St. Michael's Mount and elsewhere. Moreover, where the junction happens to coincide with the strike of the killas, this is sometimes tilted up at high angles; but very frequently, as at Cligga, Trethowel, Wheal Burn, Ponsanooth, and many other places, the junction is in a line of fault, and the granite, in its last movement, at any rate, has been, as it were, punched up through the killas, carrying upon its back thick masses of stratified rocks which have since been denuded away. The strike of the rocks is indeed very rarely altered by the intruding masses; it is only different near the granite from what is observable at some distance off, because the older rocks are there brought up to the surface by the general upheavals which no doubt preceded the actual granitic extrusions.*

---

* This is the result of two causes which have operated in the same direction. First, the denudation has been much greater westward. This is shown by Mr. Sorby's observations on the fluid-cavities in the granite, which indicate that, while the St. Austell granite solidified under a pressure equal to 32,400 feet of rock, the pressure at Ding Dong, near Penzance, was equal to 63,600. The whole of this has been removed by denudation; in fact, Ding Dong is now hundreds of feet lower than Hensbarrow. Second, it is a consequence of the mechanical movements observable in the various cross-courses, nearly all of which are faults with an eastward downthrow. The aggregate downthrow eastward between St. Agnes and Padstow is not less than 10,000 feet, with probably 5,000 feet additional between Portreath and St. Agnes.

As these comparatively large masses have so little effect in altering the strike of the sedimentary rocks, it was not to be expected that the elvan porphyries would have any effect on the strike since they only occupy fissures. In a majority of cases these elvans run nearly parallel with the strike, but either with a higher or an opposite dip. In a few cases, however, they cut across the beds nearly at right angles with the strike.

The various trappean rocks, usually, if not always, much older than the granites, have most frequently been pushed between the beds, often for several miles together, and are only occasionally seen to cross them distinctly.† This different mode of occurrence is exactly what might be expected if the trappean materials were injected while the pressure of rock above was comparatively little, and the porphyries when it was very great; in other words, the elvans are more decidedly plutonic than the greenstones.

Although the mechanical effects of the various intrusions are so slight, the same cannot be said of the succeeding chemical effects. These are everywhere visible, though they differ in their nature in different places, and the intensity and extent of the metamorphism seems to be somewhat proportioned to the extent of the intruding mass. As to the different nature of the alterations produced in the sedimentary rocks near the junctions, the gneiss and spotted schist of the north coast, near Portreath, and the tourmaline-schist of the Wheal Vor Valley and of the Hensbarrow granite are good examples.* As already observed, part of the difference is no doubt due to the originally different nature of the schists themselves, and part may be traced to the subsequent circulation of mineralized waters through the weakened and loosened junctions. Much limestone may have been in this way removed by the action of acid (siliceous) waters. This would account for many minor irregularities in the stratified rocks, owing to the collapse of the unsupported beds on either side. Many of the beds are highly silicified throughout, in the neighbourhood of the fissures, owing to the long-continued action of such waters. This is especially the case where (Lower Devonian) Sandstones are traversed by cross-courses as in the neighbourhood of Ladock.

---

* "A somewhat remarkable fact in connection with nearly all the great granitic masses which I have examined, is that, although they invariably alter the slate rocks near their junction, and send veins into them, they do not in the slightest degree affect the general strike or dip of those beds, but appear to have themselves partaken of the movements which placed those Silurian strata in their highly inclined and contorted positions, and gave them their very uniform meridional direction."—(Selwyn, quoted by Murchison, 'Siluria,' 5th Ed., p. 463.)

† That they were so thrust between the beds, and not poured over them, is further evidenced by the fact that there is no perceptible difference in the alterations of the beds lying above and those lying below the masses in question.

With regard to the relative extent of the changes produced, these are the greatest in the neighbourhood of the granitic bosses, and least in that of the elvans, which is quite in accordance with the differences in bulk of the several intrusive masses. Much more might be said on this interesting topic, but to do so would make this paper too long.†

PART II.—ECONOMIC GEOLOGY.

Mineral Lodes.

The granitic and slate rocks, especially near their junctions, are traversed by great numbers of mineral veins, containing the ores of tin, copper, lead, iron, and, occasionally, other metals; and also by many veins that contain only quartz or clay. The veins yielding ore are termed by the miners "lodes," and those filled with quartz or "spar" are known as "cross-courses," while the clay-veins are commonly called "flucans."

The lodes of tin and copper occur in both the granite and the slate, but seldom far from the junction of the two rocks; the lodes of lead and iron not only occur in similar situations, but are still more frequently found at considerable distances from such junctions. Some lodes have copper-ore only in the slate, and tin-ore only in the granite; and at Botallack mine one of the lodes was found to pass three times from granite to slate, or the reverse, containing only tin-ore in the granite and only copper-ore in the slate. The Corpus Christi lode, in which this occurrence was met with, is about 100 fathoms east of the Crowns lode, the workings of which extend nearly half-a-mile under the sea; it runs nearly parallel to the junction of the granite and slate, and as this junction is very irregular, the lode passes alternately from the one formation to the other. This part of Botallack is now abandoned.

---

* A good example of the alteration of "killas" into tourmaline-schist may be seen on the south side of the Great Carclaze open work, as well as in the adit leading to the same work. Here both the granite and slate are very schorlaceous, and this has resulted in an appearance which has led some observers to suppose that there is a transition from one to the other. A closer examination shows that this is quite erroneous.

† The pseudomorphic processes which have operated on a great scale on the Cornish rocks are mainly two, viz.: kaolinization and serpentinization· I have dealt pretty fully with the first in my Hensbarrow paper already referred to, and with the second in papers which have recently appeared in the 'Quart. Journ. Geol. Soc.' ('Serpentine and Associated Rocks of Porthalla Cove,' Aug., 1884), and in the 'Geological Magazine,' July, 1885; August, 1886; and May, 1887.

In some instances, mines which had yielded tin at first afterwards became rich for copper. This was the case at Old Tresavean in Gwennap, near Redruth, and also at Dolcoath. Some of these mines on the copper becoming worked out were abandoned. In others the workings have been continued to a greater depth, and have proved to be again very rich in tin. This has been notably the case at Dolcoath and other mines near Carn Brea Hill.

The different veins, cross-courses, &c., are plainly true fissure-veins; at any rate they are so in the great majority of instances, and in many cases it is evident that the same fissure has been opened at many different times, as might reasonably be expected; because the fissures, whether partially filled up or not, would usually be lines of weakness. This is shown by the "combed" structure often met with in mineral veins or lodes. The veins are very frequently "lines of fault," especially the "cross-courses," or north and south quartz-veins; and displacements of the rocks, causing "heaves" of the lodes at the points of intersection, are exceedingly common. The apparent displacement is usually horizontal, and sometimes extends to a distance of many fathoms; but it is evident that this appearance is produced by a vertical movement of rocks containing lodes which are inclined from the vertical, or have, to use a local term, a considerable amount of "underlie." Many lodes are partly composed of fragmentary materials which have fallen into the fissure from its sides or from above, and have been subsequently cemented together by various mineral infiltrations.

The mean directions of the tin and copper lodes are found to differ in different parts of the district; but on the whole they bear nearly east-north-east; while those of lead and iron are more frequently a few degrees east of north. The greatest deviation from the mean east-and-west direction of the tin and copper lodes occurs in the St. Just district, where they bear as much as 50° south of east and north of west. Their average bearing throughout Cornwall is about 30° north of east and south of west, a range not materially different from that of the fundamental granite mass extending from Dartmoor to the Land's End.

Some of the lodes are nearly vertical, but they mostly incline or "underlie" more or less from the vertical in different directions. The mean dip of the lodes may be taken at about 70° from the horizontal, or 20° from the vertical, having, as miners express it, an underlie of about 2 feet per fathom. The dip or underlie of the east-and-west lodes is, perhaps, more frequently towards than from the nearest granite mass. The average width of the lodes is about 4 feet.*

It should be noticed that the same lodes may within short distances vary a good deal in bearing, width, dip, and in the nature of their contents. The lodes also frequently split or divide into branches, and these branches may or may not afterwards come together again. If a lode divides into branches, and these branches again unite, the included portion of the "country" is called a "horse."

An examination of the displacements of the different veins, at the points where they are intersected by other cross-veins and by each other, has shown that some are much more ancient than others. They were divided by the late Mr. Carne, so long ago as 1822, into eight groups, according to their relative ages, and more recent observations have somewhat increased this number. Of these different sets of fissures the oldest were probably formed in late Carboniferous or early Permian times; the newest may possibly be Post-glacial.†

---

* A distinction must be noticed between the width of the lode and the width of the lode-fissure. In some instances this is the same, in others the fissure is wide while the workable part of the lode or "paystreak" is much narrower. Again, in other instances the lode-fissure is very narrow, while the "country" rock is impregnated with mineral to a greater or less distance from this fissure. All such workable material would be called "the lode" by the miner. The average width of 4ft. given above refers to the lode in the miner's sense, and not to the lode fissure.

† For good summaries of the vein phenomena of Cornwall, see Henwood, 'Journal of the Royal Inst. of Cornwall,' No. xiii, 1871, and Moissenet, 'Lodes of Cornwall,' translated by myself, 1877.

Stockworks.

A certain proportion of the tin raised in Cornwall is got, not from regular lodes, but from "stockworks," or masses of rock containing numerous small strings or veins of ore which traverse it in such a manner that the whole mass must be crushed so as to extract the ore. Of stockworks in granitic rocks, Carclaze, near St. Austell, and Cregan Rocks, near Roche, may be given as examples. Examples of stockworks in killas may be seen at Minear Downs, near St. Austell, Mulberry Down, near Bodmin, and Great Wheal Fortune, in Breage. Stockworks in elvan have also been worked at Wheal Jennings,* near Gwinear Road Station, and other places.† The underground stockwork at Pednandrea Mine, near Redruth, was well described by Mr. H. C. Salmon in the 'Mining and Smelting Magazine' about twenty years ago. Copper stockworks are much less common than those yielding tin, but they have been met with at Bunny Mine, near St. Agnes, and elsewhere.

Tin Stream Works.

Formerly a large proportion of the tin-ore raised in Cornwall was obtained from ancient river-gravels. These, with the various modes of working, were fully described by the late Mr. W. J. Henwood in 1872.‡ At present this mode of working is almost entirely a thing of the past, most of the deposits having been worked out. A few straggling tin-streamers may be met with occasionally working over again the old heaps of *débris*, but so much is the industry a thing of the past that even the name has been adopted by the people who work over the sands and slimes washed down from the various mines. Large quantities of good machinery have been erected in the Red River near Camborne, and elsewhere in Cornwall, for this purpose, and the tin-ore so obtained forms a very important proportion of that obtained in Cornwall, amounting in some years to over 1,000 tons, or about 10 per cent. of the total yield of that particular district.

The alluvial tin gravels extend beyond the present valleys into the sea, where, of course, they cannot be worked. Attempts have, however, been made to work them under the water at Restronguet, near Devoran, in Falmouth Harbour, and at Helston under the Looe Pool. The latest attempt was described by Mr. C. D. Taylor in a paper read to the Institute of Mechanical Engineers in 1873. The works have been since abandoned as unprofitable.

---

* See Mr. G. Seymour, 'Trans. Roy. Geol. Soc. Corn.,' Vol. ix, p. 185.

† For a general account of the numerous varieties of tin-ore and its differing modes of occurrence in Cornwall and Devon, see the illustrated papers by the author on "Cornish Tin Stones and Tin Capels," in the 'Mineralog. Mag.,' Vols. iv and v, 1880-1882.

‡ 'Journ. Roy. Inst. Corn.,' xv, p. 191.

Lode-Workings.

The various ores being found in veins of very similar character, sometimes two or more in the same vein, the process of exploitation may be dealt with generally.

In consequence of the great inclination of the lodes from the horizontal, averaging 70°, the mode of working is necessarily quite different from that adopted in the case of beds that are inclined but little from the horizontal, such as the beds of iron-ore and coal in the centre and north of England. The difference is, indeed, extreme in all the important points, the ores being in irregular, comparatively thin, and nearly vertical veins, instead of regular, thick, and nearly horizontal beds. Again, the material composing the ore-veins contains in general but a very small proportion of saleable ore, in the case of tin seldom more than one per cent. of the whole mass in any given mine; while that portion which is raised to the surface rarely yields more than two to four per cent. of saleable produce instead of the 25 to 60 per cent. of the iron-ore or coal in the other districts. In some stockworks, indeed, the saleable ore does not exceed one quarter per cent. of the stuff treated. The iron lodes of Cornwall and Devon are, however, much richer than the lodes of tin, copper, and lead, from 60 to 95 per cent. of the material raised being merchantable ore.

With but few modifications the following mode of working is universally adopted throughout the Cornwall district, and, indeed, elsewhere for similar deposits of ore. The position of the lode at surface, its bearing and underlie, having been determined as accurately as possible, one or more shafts are commenced at suitable points. These are frequently sunk on that side of the lode towards which the underlie is, or they may be sunk between two lodes, so as to serve for working both of them. The shafts are almost invariably rectangular in plan, and the first portion, at least, is sunk vertically, although when the lode is reached the shaft is very frequently continued upon it and following its underlie. Frequently, however, the more modern shafts are sunk vertically for their whole depth. A very few, such as the diagonal shaft at Botallack Mine, are carried down inclined throughout, following the course of the lode.

Whenever the inclination of the surface is considerable, a tunnel, or "adit," is driven from the nearest valley or watercourse available directly into the hill in which the lode is situated, so that all the water from the portion of the mine above that level may drain away by the adit. This serves also to carry away the water pumped from the deeper levels, which would otherwise have to be raised to the surface. In some mines, where the water is required for the purposes of dressing the ore, the adit is of but little importance; but in others, where there is an abundant supply of surface water for dressing purposes, the saving effected by the adit is often very great. Sometimes one large adit is made to carry away the water from many mines by means of branches, and one such adit recently completed in Germany is upwards of fourteen miles long. Even this is eclipsed by the Great County Adit of Cornwall, which is situated near Redruth. This adit, with its branches, is upwards of thirty miles in length, and was made by Mr. Williams, of Scorrier, near Redruth, about the middle of the last century. It is at present of comparatively little importance, many of the principal mines for which it was constructed being worked out and abandoned; but some few years ago it drained an area of 5,550 acres, and discharged on an average no less than 1,450 cubic feet of water per minute. From this water in the years 1864 to 1867 about twenty-three tons of copper were annually obtained by precipitation upon wrought iron. The adit discharges into the Carnon Stream, the outfall of which is into Restronguet Creek. The mouth of the adit is 39 feet above high water, and the fall along its course from the distant portions to the mouth ranges from about 50 to 80 feet.

Very large quantities of water have to be raised from the mines, in some instances reaching from 1,000 to 2,000 gallons per minute. For pumping purposes the engines are almost always of the single-acting "Cornish" type, of which many fine examples are to be seen within the Cornwall district. Although the duty of these engines has from various causes greatly fallen off within the last thirty years, their performance will still as a whole compare favourably with that of the engines of any other mining district.

The large pumping engines at Dolcoath will be well worth the attention of the Association.

The adit is sometimes driven on the course of the lode, in which case it constitutes a true "level;" at others, in a transverse direction, when it would be more properly termed a "cross-cut." Other levels are then usually driven at distances of 10 fathoms, or 60 feet apart, both above and below the adit; and these are sometimes driven on the lode, and sometimes by its side, but always following its course. The underlie of the lode makes these levels appear in the plan as so many parallel or approximately parallel lines; and in the vertical longitudinal section they will, of course, appear as parallel lines one beneath another. As the levels become extended to great distances from the shafts, smaller shafts, called "winzes," are sunk from one to another, not only for the purpose of ascertaining the value of the lode, but also for ventilation. When the shaft is not sunk "on the lode," that is, following the direction of the lode, the communication with the various levels is effected by cross-cuts; and similar cross-cuts are also frequently driven from one lode to another.

The lodes in some parts contain very little of the ores sought for, being filled with vein-stuff of little or no value, or they may be so thin as not to pay for working; but at other times they swell out, and rich bunches of ore are found. In some mines the lodes, which were rich at first, have become poor for hundreds of feet in depth, and have yet proved to be rich at still greater depths. This has been pretty generally the case with the mines around Redruth and Camborne, Dolcoath mine being a notable example. This was formerly one of the richest copper mines in the world, but from about the 130 to the 180 fathom-level below the adit it was found to be exceedingly poor; below the latter level, however, it has yielded very large quantities of tin; and the present bottom level, which is 400 fathoms below the adit, and about 435 fathoms from the surface, is very rich indeed. Where the lodes are rich enough to make it worth while, the ore is often dug out completely. Frequently, however, in large mines, some of the richer portions are left as reserves, to be worked should the bottom of the mine become poor, and to pay the expenses of further explorations.

The miners are usually paid for sinking shafts or winzes, and for driving levels at a certain rate per lineal fathom: this is called, "tutwork." Common dimensions are :—

		Feet.		Feet.
Engine shafts ...	from	8 × 6	to	12 × 9
Air shafts and winzes ...	„	4 × 2	„	6 × 4
Levels ...	„	6½ × 2½	„	7 × 5

Levels are frequently made somewhat larger at bottom than at top. Timbering, when required by the nature of the ground, is frequently done by the miner as part of his bargain, and the excavated material is drawn to the surface at his cost. Sometimes, however, the timbering is done by special timber-men, and the ground broken is raised to surface on "owner's account." The prices of sinking or driving vary much according to the nature of the ground, the depth from surface, the area of cross-section, and many other particulars; but the following prices, many of which have been recently paid within the writer's knowledge, will give some general idea of the labour-cost of such works. For greater convenience the prices have been calculated to cubic fathoms instead of lineal; and they are subject to deductions for all such materials as explosives, candles, and tools supplied to the men from the stores of the mine.

For sinking shafts in soft killas, or clay ground :—

	£		£	
Near the surface, say less than 20 fathoms in depth	2	to	3	per cubic fm.
Below about 20 fathoms	3	„	4	„

For sinking shafts in compact killas, or "pick and gad" ground :—

	£		£	
Near the surface	4	to	6	per cubic fm.
Below about 20 fathoms	5	„	8	„

For sinking shafts in "fair blasting ground" :—

	£		£	
Near the surface	6	to	20	per cubic fm.
Below about 20 fathoms	10	„	30	„

Levels are, perhaps, one-third cheaper for non-blasting, and half cheaper for blasting ground. In very easy ground small adit levels, which do not require to be timbered, may be driven for 5s. or 6s. per fathom.

In extreme cases much higher prices have been paid; thus at East Pool Mine, near Redruth, as much as £37 per cubic fathom has been paid for sinking in granite; and £24 per cubic fathom for cross-cutting in the same rock. At North Pool Mine £51 per cubic fathom has been paid for driving a level in greenstone, and the same price has been paid at Heytor Vale Iron Mine, near Bovey Tracey, in Devon. A portion of a shaft in greenstone at North Roskear Mine, near Camborne, is said to have cost nearly £500 per fathom of depth, the dimensions of the shaft being 12 feet × 8 feet, equivalent to £180 per cubic fathom.

To avoid sending too much of the vein-stuff, or waste, to the surface with the ore, the parts of the lode between the levels are often removed by "tributers," who are paid a certain percentage upon the value of the ore raised, the rate varying from a few pence to 15s. or 16s. in the £; so that it is to their interest to keep the waste or "deads" separate from the ore. When the lode is very rich, however, or very even in quality throughout, it is usually removed by "tut-workers," or "stopers," who are paid at a fixed rate per ton; a common price for stoping in moderately-hard blasting-ground being 3s. per ton.

In metal mines, the lode and the containing rock called "country," are either, or both of them, very frequently so hard that it is necessary to blast with gunpowder, dynamite, or other explosive. The use of some form of safety-fuse in blasting is, the writer believes, a universal practice.

For the means of conveyance in the mines, tram-roads are every year becoming more common, upon which the stuff is conveyed by waggons pushed by hand; but there are still some mines in which all the stuff is conveyed along the levels in wheelbarrows. When it reaches the shaft, it is loaded into "kibbles" or into "skips" and conveyed to the surface. The kibbles are iron buckets hanging free in the shaft, and the skips rectangular boxes having rollers running upon guide-rods fixed in the shaft; the latter plan being used more particularly for working in inclined shafts. In shallow mines the ores are raised by means of a hand-windlass or tackle, and in deeper ones by a horse-whim or steam-engine. As a rule the machinery for raising the ore is greatly inferior to that used for draining the mines. The stuff is drawn to the surface in quantities varying from 1 cwt. to 1 ton, and with a somewhat slow rate of motion. This is in part owing to the smallness and irregularity of the shafts in many of the oldest mines, and in part to the fact that the winding engines are very frequently used in addition for stamping purposes. In the larger mines the use of wire rope for drawing or hauling purposes is now almost universal.

The ventilation of the mines is almost always effected by natural means, and is now rarely very defective, except in those places where exploratory works are being proceeded with. In some cases, however, some artificial means of ventilation on a large scale is very much to be desired; but the absence of any combustible emanations renders this less a matter of absolute necessity than in coal mines. Lamps are unknown in the Cornish mines, the work being invariably carried on by the somewhat expensive aid of tallow candles; a lump of clay serves as a candlestick to attach the candle either to the "hat-cap" of the miner, or to the side of the level in which he is at work.

The miners usually go to and from their work by means of ladders placed almost vertically; occasionally they are raised and lowered by means of the skip used for raising ore, or by a special skip kept for this purpose—as at East Pool Mine—but in a few of the larger mines a peculiar contrivance, called the "man-engine," is now employed. This, which may be seen at Dolcoath and Tincroft Mines, consists of a vertical beam of wood called the "rod," which is made to move alternately up and down through a space of twelve feet, by means of a steam-engine or water-wheel. On the rod, steps of wood, about a foot square, are fixed twelve feet apart, upon which the men stand while the rod is in motion, holding on by iron loops fixed on the rod for that purpose. When the rod stops at top and bottom of the stroke, its steps are level with little platforms called "sollars," which are fixed in the sides of the shaft. By standing on the steps of the rod during its upward motion only, and on the sollars while it moves downwards, the men are raised to the surface by successive lifts of twelve feet, or two fathoms, without any labour on their part beyond stepping from the rod to the sollars and back again. As many men may thus be brought up from their work at one time as there are steps on the rod, and as the sollars are fixed on both sides of the shaft, an equal number of men may be carried down at the same time, each descending man stepping on the rod as the ascending man steps off, and *vice-versâ*. The man-engine is so great an advantage to all concerned, that it would soon become generally used were it not that most of the shafts in old mines are too narrow and also too crooked to admit of its introduction ; the cost of the rod itself and of its fittings is also very considerable.

China-stone and China-clay.

China-stone is a kind of metamorphosed granite, the felspar being in a very decomposed condition, and the quartz by no means so distinct as in pure granite. It is largely used for making fine pottery, but is of little value for use in the potteries unless mica is either entirely absent or exclusively of white non-ferruginous varieties ; and there should also be no schorl present. Although it seems so soft and decomposed, it forms a most excellent building-stone, as may be seen in the towers of St. Stephen's, Probus, and other churches.

China-clay, in its natural condition, is very much the same as china-stone ; but the decomposition has gone still further, the felspar being here completely changed into clay ; and nothing more is necessary for extracting the clay than the disintegration of the whole mass by water, by which the clay is carried away in suspension.

The deposits from which china-clay is obtained are very irregular in their occurrence. They seem to be portions of the various granite masses decomposed *in situ ;* and they often cover a considerable extent of surface. Their extent in depth is unknown, but at Beam Mine, and also at Rocks Mine, both near St. Austell, china-clay was found at a depth considerably exceeding 60 fathoms from the surface. The situation of masses of china-clay is frequently indicated by slight depressions of the surface, and they are often crossed by lodes and branches yielding tin-ore of a very pure kind. At Carclaze, near St. Austell, one of the largest of these deposits was worked from the time of Edward IV. until the present century, simply as a tin mine or stock-work by open cutting, for the sake of small veins of good tin-ore that intersected it, and the china-clay removed in getting the tin-ore was washed away to the sea through an adit, its value not being known ; this excavation for china-clay now extends to a depth of 25 fathoms, a length of a quarter of a mile, and an area of about 13 acres. Many similar but smaller excavations are to be seen in the same neighbourhood.

In the rock from which the china-clay is obtained, the felspar of the original granite is often seen to have existed in crystals of considerable size; and these retain their form and position, but are completely altered to kaolin or china-clay. To make this clay marketable, it is only necessary to break down the soft decomposed rock, and direct a stream of water over it, when this water becomes at once thick with the suspended particles of the clay and the mica, with which it is always accompanied in considerable quantity. The milky stream is then guided into narrow channels called "micas," in which the current receives a check, and the heavier particles of mica are deposited. The clay is finally settled in large tanks or "pans," and afterwards dried, often by exposure to the air, but mostly by means of heated flues or "drys," over which the partially consolidated clay is placed for the purpose. As soon as the clay is dry it is ready for sale, being carted at once to the shipping ports in a loose state, or packed into barrels or bags for exportation. It is much used for the finer kinds of pottery, but large quantities are used for paper-making, "bleaching," and other minor industries. The process of washing and drying china-clay will be seen in operation at Carclaze and at the West of England Works at Nanpean.

The deposits of china-clay occur in connection with each of the separate granite masses, but the most important of those at present in work are situated near St. Austell, in Cornwall, and at Lee Moor, in Devon.

Considerable quantities of the refuse of the china-clay works have been worked up into most excellent fire-bricks, thus laying the foundation of another industry. The county of Cornwall also yields large quantities of granite and roofing-slate of first-rate quality.

At present tin-mining is by far the most important of the Cornish mining industries, in fact, the tin production shows no signs of falling off; but the amount of copper produced has fallen off so greatly that in many parts copper-mining is a thing of the past. This is partly due to the exhaustion of the deposits and partly to the very low value of copper, due to the enormous production of the Spanish and American mines. Arsenic and wolfram are important products, and small quantities of lead, zinc, iron, and other metallic ores are still raised in Cornwall; but here, too, the low prices obtainable have compelled most of the mines yielding only such ores to close.

The annual production of china-clay and china-stone is very great, and shows no sign of lessening; but here, too, the low prices of the past twelve years have told heavily on the producer.

The following table gives the total mineral production of Cornwall for the year 1885, as stated by the Mining Inspector —

	Tons.	Value. £
Tin-ore	14,323	659,935
China-clay and stone ...	312,413	234,310
Copper-ore	19,734	51,111
Arsenic	4,088	27,499
Wolfram	374	4,799
Lead-ore	241	2,001
Zinc-ore (blende) ...	1,031	1,812
Ochre, &c.	600	364
Fluor-spar	108	134
Iron-pyrites	3	1

All the tin raised in the kingdom comes from the two westernmost counties and three-fourths of it from the foot of Carn Brea Hill. In 1885, seventy-nine mines in Cornwall produced 12,833 tons of dressed tin-ore, and 3,812 tons of undressed, the total value being £608,863. The Cornish production for 1885 was nearly 800 tons less than in the previous year, and about an average for the last ten years.

All the arsenic raised in the United Kingdom during the year came from Devon and Cornwall. Twenty mines in the latter county produced 4,088 tons, of the value of £27,499. The mine producing the greatest quantity in Cornwall was Holmbush, Stokeclimeland, 1,748 tons, which sold for £14,359; East Pool, 568 tons, £3,638; Okel Tor, Calstock, 430 tons, £3,460; and Wheal Agar, 297 tons, £1,885, came next.

Out of 36,241 tons of copper ore mined in the United Kingdom, upwards of 34,000 were credited to Devon and Cornwall. From the latter county (35 mines) came 19,734 tons, worth £51,111. The metal obtained by smelting the ore was 1,578 tons.

Six mines in Cornwall produced 241 tons of lead-ore, yielding 160 tons of metal and 2,500 ounces of silver. The value of the ore at the mine was £2,001. Old Shepherds received £1,215 of that amount, and East Wheal Rose £456.

East Pool sold 374 tons of wolfram, realizing £4,799. Zinc-ore was raised in six mines in Cornwall, the total quantity being 1,031 tons, worth £1,812. Duchy Peru produced the largest proportion of it, 840 tons, worth £1,398. Old Shepherds, close by, raised 98 tons, which sold for £289.

The shipments of china-clay and china-stone from Cornwall during 1885 were :—Fowey, 114,403 tons ; Par, 86,325 ; Charlestown, 59,690 ; Pentewan, 24,960 ; Plymouth, 10,215 ; Newquay, 4,152 ; Penzance, 1,570 ; Padstow and Wadebridge, 1,495 ; Penryn, 1,024 ; Porthleven, 860 ; Hayle, 390 ; Laira, 170 ; St. Agnes, 150 ; and sent to inland towns by Cornwall Railway, 3,638 ; total 312,413 tons, valued at £234,310.

The number of persons employed in the 134 Cornish mines worked in 1885, was 12,473, of whom 6,687 worked underground, and 5,786 at surface. Tin streams gave employment to upwards of 1,200 more, nearly 900 being engaged on the 30 stream works on the Red River, and upwards of 150 on the river from Wheal Basset to Portreath. The clay works in Cornwall employed about 1,800 persons, of whom 335 were in the pay of the West of England Company.

Collections of Rocks and Minerals.

The short time at the disposal of the Association will not allow the collection *in situ* of any large number of rocks and minerals among the igneous rocks ; however, it will be easy to get several varieties of normal granite, china-stone (Petuntzite), china-clay rock (Carclayzite), schorl-rock, quartz-porphyry, felspar-porphyry, felsite, mica-trap, diorite, and dolerite. Among bedded rocks, the most interesting will be tourmaline-schist from near Carclaze, and hornblende-schist, and mica-schist, from the Lizard district. From the same district will be obtained several varieties of gabbro and serpentine. Among minerals, fine examples of schorl may perhaps be got at Carclaze, with possibly good crystals of cassiterite ; various tinstones from East Pool and Dolcoath (not forgetting the "blue-peach capel"); uncleavable fluor-spar, dolomite, and wolfram from East Pool, with, perhaps, crystallized chalcopyrite, acicular bismuthenite, and massive smaltite ; also crystals of sublimed arsenious acid from the "burning-houses." At Messrs. Bolitho's tin-smelting works, interesting tin-droppings and tin-crystals (described by Dr. C. O. Trechmann in the 'Mineralogical Magazine,' Vol. iii, p. 186) may be obtained. At Wheal

Cock Cliffs, St. Just, crystallized hornblende, epidote, axinite, apatite, and other interesting minerals may be got ; and at Levant mine, rich grey copper-ore. At St. Michael's Mount most of the minerals mentioned in Sir W. W. Smyth's description may be seen, but must not be broken from the rocks.

On the whole, taking into account the specimens likely to be obtained from the various mine-burrows, the known generosity of the Cornish mine-captains, the various cliff-sections, and the beautiful worked serpentine sold by the dealers in Penzance, Helston, and Kynance, most of the members are likely to be well loaded on their return to London. At Truro Museum the mineral collection is well arranged, and printed catalogues are obtainable. A few very interesting Cornish fossils may also be seen there. At Penzance, the mineral collection is very beautiful and well arranged, and there is here also a very fine collection of Cornish fossils. The Carne Museum should also be seen at Penzance.

NOTES ON THE LONDON CLAY AND ITS DEPOSITION.

BY J. STARKIE GARDNER, F.G.S.

The London Clay is an essentially marine formation, and is distinguished as the only member of the Eocene Series which extends over the entire London and Hampshire basins. The bight of the London Clay stretched from Southwold to the N.E. and Canterbury to the S.E., in a westerly direction almost to Dorchester; and on the Continent it has been said by Prestwich and others to extend northward from Dieppe through Cassel, Lille, Tournay, and to Calais, St. Omer, &c., covering, in fact, a large part of French Flanders and Belgium. A glance at the map suffices to show that though now cut through by denudation it was formerly continuous, but its existing western, south-western, and northern boundaries in England seem to approximate in some degree to its original limits in these directions. Prestwich considers its transverse section to be 200 miles, while its axis tends slightly north of E. and W., and is much longer.

The great bulk of the London Clay is a fine, compact, tenacious, dark-blue clay, weathering brown. It is the most massive and homogeneous of British Eocene formations, and exceeds all others no less in thickness than in horizontal extent. At Newbury it is

50 feet; Alum Bay, 200; Whitecliff Bay, 300; London, 440; Sheppey, 480. Thicknesses on the Continent are given as follows: Cassel, 400; St. Omer, 350; Lille, 150. An ideal section, somewhat oblique to the axis, has been published by Prestwich (Fig. 1).

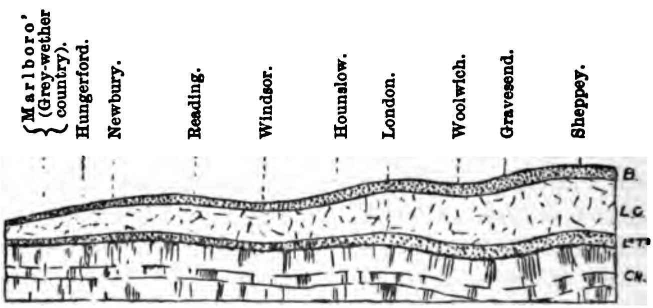


FIG. 1.—Ideal Section of the London Clay. (After Prestwich).

B. Bagshot Series. LR Ts. Lower Tertiaries.
L. C. London Clay. CH. Chalk.

It would appear that if ever a name implying the quality of the deposit might with propriety be applied to a formation, it would be in the case of the London Clay; but even here this is attended with inconvenience, and we are forced to call "clay" that which is not clay at all. The blue clay so largely developed under London and at Sheppey is but one phase of a formation which comprises sands, shingles, limestone, ochreous earths, etc.

The London Clay rests in the east at Herne Bay upon a mass of sands and shingle called the Oldhaven beds, which in turn rest upon a shallow sea-water deposit—the Thanet beds. Towards London a series of brackish and nearly fresh-water fluviatile beds are intercalated between the Oldhavens and Thanets, and about Woolwich a thin, scarcely discernible tongue of mottled clay first interposes between the brackish and slightly-brackish Woolwich beds and the Thanets. This rapidly thickens, and as we proceed west, first the Oldhavens, or sea sands and shingle, and then the brackish and slightly-brackish fluviatile beds die out, while the mottled clay thickens and the London Clay comes to rest directly upon it. Thus the London Clay successively overlaps, in contact, the Oldhaven, the Woolwich, and the Reading beds; and, without contact, the Thanets.

I have called attention to the intimate relation existing between the Oldhaven and the London Clay ('Q. J. G. S.,' 1883, p. 206) at Herne Bay. Little lenticular patches of true London Clay are imbedded in the sands of the former, and there is no need to insist that the passage from sand to clay does not indicate any interruption whatever in deposition. Sharp sea sands and well-worn shingle, sometimes accumulated in enormous masses, as near Bickley and Bromley, usually usher in the London Clay in Kent; and loamy sands with scattered pebbles do so in Essex. In Berkshire its sandy base bed is relatively insignificant, and true London Clay rests almost directly upon the fresh-water Reading beds beneath. In Sussex and Hampshire there is generally fine sea sand at the base, and near its extreme confines, in Dorset, it is replaced by shingles and sand and oyster-beds. In West Kent, Surrey, and Middlesex, where the London Clay has the brackish Woolwich beds beneath it, the passage is in some cases gradual, and the London Clay is linked to the beds below by the occurrence of *Melania* and *Cyrena* in its basement bed.

These generalizations are merely intended to show that the connection between the London Clay and the Oldhaven and Woolwich beds is intimate, and that the deposition, though altered in character, may possibly, or even probably, have been continuous. The contact between the London Clay and the Reading beds on the other hand is always, so far as I have observed, abrupt and unconformable. In the Isle of Wight the mottled clay has been eroded and cut into pebbles, and at Coldham, near Winchester, a freshwater leaf-bed has been broken up and redeposited in the marine fossiliferous sand of the London Clay basement bed.

Just as the London Clay deposition begins with littoral and brackish deposits, so it ends, when the series is complete, with sandy clays, sands, and shingles, as on the heights round London and to the east. At Alum Bay the upper 40 feet is separated from the main mass by 18 feet of sand, and the series closes with several similar beds of fine sand, which are much finer than those of the Lower Bagshot, and are distinguished from them by the presence of flint grains. The series closes in the same way at Whitecliff Bay, and similarly in places in Dorsetshire. These marine sands and shingles, which are conformable with the London Clay, have been confused with the unconformable fresh-water Lower Bagshots, which succeeded, and no doubt greatly eroded, the London Clay in the area west of London.

The fauna of the London Clay varies with the quality of the matrix. In Dorset it is full of oysters, and there is every indication that the water was exceedingly shallow. In the Isle of Wight the fauna consists almost entirely of bivalve shells, such as *Panopœa*, *Pholadomya*, *Pectunculus*, *Pinna*, and *Cardita*, all presumably shallow-water species. At Portsmouth, beds of sand alternated with the clay and contained a rich fauna, with *Pyrula Smithii*, *Cassidaria diadema*, *Rostellaria lucida*, *Trophon*, *Voluta*, and others, in the main distinct from any found elsewhere. The Bognor fauna is also peculiar, and not indicative of deep water, some beds being crowded with *Pinna*, *Pectunculus*, *Panopœa*, and *Vermetus*. The fauna at Clarendon is much like that of Alum Bay, but with many univalves. The fauna of the sandy beds at the top of the London Clay round London is again exceedingly rich, but quite distinct in facies from any previously mentioned. All these may be classed as the shallow-water and purely marine beds of the London Clay, and might have been separated from each other by certain intervals of time.

The main mass of the London Clay was deposited, however, in a depth of at least 100 fathoms. Prof. Rupert Jones is enabled to make this statement from the *Foraminifera*; Prof. Prestwich has inferred it from the abundance of *Cephalopoda* and *Echinodermata*. Under London the shells of *Nautilus*, in magnificent preservation, abound, and more rarely those of *Voluta*, *Fusus*, *Cerithium*, and *Phorus*. At Sheppey the marine fauna is similar, but it is supplemented by innumerable spoils from the land, comprising turtles, and the disintegrated carcases of crocodiles, snakes, birds, and even monkeys and dead fish, accompanied by swarms of crabs, which doubtless fed upon them. With all this animal life are mingled innumerable abraded twigs and fruits and seeds of tropical plants. The deeper part of the London Clay betrays the presence, as pointed out by Prestwich, of powerful fluviatile action, which swept down into this Eocene sea vast argillaceous sediments and rich stores of plants and animals. Farther east, at Swale Cliff, on nearly the same horizon, fruits are much rarer, though twigs are still very abundant; and at Harwich and Felixstowe fruits are absent, whilst twigs are present in enormous quantities.

This rapid and imperfect sketch of the leading physical features of the London Clay will suffice to enable us to consider how it came to be deposited. Its deposition was a geological event, the history of which is clearly written in its deposits.

The Thanet Beds which underlie, but nowhere come in direct contact with the London Clay, resulted from a small wave of depression which introduced for a brief period a shallow sea as far west as Reading. In the west it speedily gave way to fresh-water deposits; but in the east it maintained itself for a considerable time, and contained a fauna of temperate and almost northern aspect. I am inclined to think that it had retired altogether from the English area prior to the London Clay, and that its site was dry. The mottled clay, or Reading beds, which the London Clay overspread and cut into in the west, is a magnificent and somewhat mysterious formation, comparable in mass and quality to the mottled clays of the Wealden. No one has written very definitely about it, but Prestwich finally regarded it as due to the decomposition of granite and basaltic rocks to the west: it is certainly identical with the fresh-water clays of Dorset, and quite unlike any known marine deposit. There are unquestionable river deposits, with plants beneath, at Reading, and above them near Winchester; and though the mottled clay is itself destitute of any, this is probably due to the mottling process. The mottling process has almost obliterated the bedding, which is, however, occasionally traceable, as at Reading. I think, for various reasons, that long contact with sea water may have induced the mottled appearance. Bones of *Coryphodon* and *Gastornis* were obtained from it at Croydon by Mr. Klaassen.* It must, I think, be accepted as a purely fresh-water, and perfectly homogeneous river deposit, but of enormous magnitude, for it crosses the Isle of Wight with a thickness of over 100 feet, and maintains its characters far into the Paris basin. The axis of the formation lies a little S. of E. and W., indicating the direction of the river, and its extent over at least 30,000 square miles implies that the river was on the largest scale, and that there was a land area of continental dimensions behind it. The presence of the plane and alder, but particularly the absence of any approach to sub-tropical types in the flora, show that the climate was somewhat like our own, and negative the idea that any part of the mottled clay and London Clay could have been contemporaneous. We must picture, just before the deposition of the latter, a low-lying tract of land over the Eocene basin, with a river of enormous volume passing towards France, either along, or south of, and parallel to, the Weald. Under these conditions a gradual and long-sustained depression set in off Essex, permitting the North Sea to slowly spread over the land, and ultimately to divert the outfall of the river from far away to the south beyond Paris, into a position not far removed from that of the present mouth of the Thames.

---

* See 'Proc. Geol. Assoc.,' Vol. viii, p. 241, and Vol. ix, p. 350.

In advancing on a flat shelving coast the sea would roll before it and lay down over its bed masses of shingle and sand. These are the Oldhaven beds. As the river began to find its way into the new area of depression and to meet the encroaching sea, estuarine beds of brackish water would be formed. These are the Woolwich beds. Then, as long-continued depression broadened and deepened the estuary until it became open sea 100 fathoms deep, every trace of fresh water would disappear, but the dead carcases of animals, and the fruits and *débris* of the forests, would be borne down by the current and become waterlogged and sink after sufficient immersion. Rafts of vegetable matter, of broken-up twigs, fruits, seeds, and conspicuously the abraded leaf-stalks of fan-palm are met with, covering the surface of the sea for miles at the mouth of great tropical rivers, and such for ages must have floated on the London Clay sea over Sheppey. The woody fruits of innumerable palms drifted past London and found their resting-place there; other lighter fruits swept on, to sink over the spot occupied by Swale Cliff, whilst twigs and brushwood floated beyond and sank in enormous quantities by Harwich and to the north. The decaying carcases supported a numerous colony of crabs of kinds that are only found abundantly in the London Clay at Sheppey. Some corals and star fish add further indications of deep water, and the addition of encrinites to the fauna at Harwich show that the depth continued to increase eastward.

As the depression carried the sea with it farther inland the waters would become more sheltered, and their littoral be no longer marked by clean, surf-beaten shingles and sands, but by more muddy sands, such as we meet with near the shore in Pegwell Bay at the present day. Much of the basement bed of the London Clay is of this nature in its central area. Still farther west, in places where the water was almost land-locked, there would be little, if any, littoral deposit preceding the fine silt.

The depression having reached its maximum, which must at Sheppey have been fully 1,000 feet, was succeeded by upheaval which caused the river to again shift its outfall, and instead of continuing eastward into the German Ocean, to pass southward in somewhat its original direction. A deep bay or arm of the sea, would consequently be left in the London basin, which gradually retreated and silted up under the influence of elevation. The littoral zone would, under these circumstances, close in with the retreating sea, and leave dry areas behind, with a good deal of blown sand. There might be lagoons and salt marshes, forming more or less extensive patches of clay, and perhaps large indents, like Pagham or Poole harbours, with great drifts or bars of pebbles and sand. There being no longer any river laden with silt, the beds last formed would be cleaner or more sandy, and quite a different fauna would live on the sea bottom. Lastly, in its eastern area, where least sheltered, the retreating sea would leave behind it strands of surf-beaten shingle and sand, similar to that which accompanied its advance.

Examples of the former deposits exist in the highly fossiliferous sandy beds of the London Clay round London, and of the latter in the Lower Bagshots of the same area. There are masses of shingle and sand remaining elsewhere; but the Lower Bagshot river, which passed over part of the ground, must have swept much away in intervening areas.

These are, of course, to a great extent mere speculations, but it is obvious that if the river had continued in the same direction during the re-elevation, the closing beds of the London Clay would have been wholly different in character, and there would have been a passage through brackish to fresh-water beds, which is nowhere the case. The deposits of the fresh-water reaches of the London Clay river do not exist, for they must have been situated far to the west or south-west, and have long since been submerged. The foliage of the trees which shed the Sheppey fruits can never again see the light. That the London Clay occupied an enormous time in its deposition is to be inferred from its great thickness, and scarcely less so from the immense change in the climate that accompanied it. It began in a temperate climate and closed under one that was little less than tropical. Yet it is quite apparent, as stated by Prestwich, that the London Clay sea was open to the cold currents of the north, for its mollusca are very much more temperate than those of the Bracklesham sea, which opened to the south, and scarcely ten per cent. of the species range from one to the other. Both equally are merely the littoral deposits of seas which had probably an oceanic extension, and whose greater depths have never been upheaved.

A natural classification, it will be gathered, would in my opinion be the following :—

London Series	Upper beach deposits = Marine Lower Bagshot beds.
	Sandy clay.
	London Clay.
	Brackish beds = Woolwich beds.
	Lower beach deposits = Oldhaven beds and basement bed.

The Lower Bagshot and the Reading beds would be distinct formations of fresh-water origin. The Thanet beds, Middle Bagshot and Upper Bagshot are also distinct formations, the former wholly, and the latter chiefly marine. These, if the fluvio-marine series of the Isle of Wight is placed in the Oligocene, complete the Eocene system in England, but it must not be forgotten that beds with plant-remains are found in the trappean series of Ireland and Scotland which belong to horizons below the Thanets, not otherwise represented in Great Britain.

VISIT TO THE HISTORICAL AND TYPE COLLECTIONS IN THE GEOLOGICAL DEPARTMENT, BRITISH MUSEUM.

SATURDAY, MARCH 12th, 1887.

Director: Dr. HENRY WOODWARD, F.R.S.

(*Report by* THE DIRECTOR.)

The Members assembled in the Central Hall of the Natural History Museum, Cromwell Road, whence they proceeded, under the guidance of Dr. Henry Woodward, F.R.S., the Keeper of the Department of Geology, to visit a newly-opened Gallery (No. 11), in which had been arranged, in seventeen cases, a series of nine Collections of historical and palæontological interest, bearing upon the early history of the British Museum and the study of Geology and Palæontology in this country. Dr. Woodward addressed the Members as follows:—

"Taking the exhibition cases in chronological order, the earliest is the 'Sloane Collection.' This is the most ancient portion of the Geological Collection, having formed a part of the museum of Sir Hans Sloane, Bart., F.R.S., acquired by purchase for the nation in 1753.

"The geological specimens are stated to have consisted 'in what by way of distinction are called *extraneous fossils*, comprehending petrified bodies as Trees or parts of them; Herbaceous plants; Animal substances,' &c., and reported to be 'the most extensive and most curious that ever was seen of its kind.' Until 1857 the Fossils and Minerals formed one collection, so that a large part of the 'Sloane Collection' consisted probably of mineral and not organic bodies, but in any case only about 100 specimens of invertebrate fossils can now be identified with certainty as forming part of the original Sloane Museum. Each specimen in the Sloane Collection had originally a number attached to it, corresponding to a carefully prepared Manuscript Catalogue, still preserved, which contains many curious entries concerning the various objects in the Museum. In the course of more than 130 years, many of these numbers have been detached from the objects or obliterated by cleaning. But as all fossils at this early date were looked upon merely as curiosities, but little attention was paid to the formation or locality whence they were derived. Historically, the collection has immense interest to us, marking the rapid strides which the science of Geology has made of late years, especially as regards its more careful and systematic methods of study.

"The next Collection is the 'Brander Collection,' and is the earliest one in which types of named and described species have been preserved. This Collection was formed by Gustavus Brander, F.R.S., F.S.A., in the earlier half of the last century, and an account of the same, with eight quarto plates, was published in 1766, entitled, 'Fossilia Hantoniensia Collecta, et in Musæo Britannico deposita.' The description of the species given in the work were written by Dr. Solander, one of the officers of the British Museum. They were 'collected in the County of Hampshire, out of the cliffs by the sea-coast between Christchurch and Lymington, but more especially about the cliffs by the village of Hordwell, nearly midway betwixt the two former places' (*op. cit.* p. 111). Only a small number out of the original 120 figured specimens are now capable of being identified, the rest having become, in the course of 120 years, commingled with the far more numerous and later Eocene Tertiary acquisitions, and so have lost their connection with this admirable Memoir. The engravings of the shells are equal to any modern published work descriptive of the fossils of the Eocene formation ; but the names given by Dr. Solander are in many instances incorrect, according to our present knowledge of the genera of Mollusca.

"The next series to which I would direct your attention is the Collection of William Smith, LL.D. This Collection, which was commenced about the year 1787, was purchased by the Trustees in 1816, a supplemental Collection being added by Dr. Smith in 1818. It is remarkable as the first attempt made to identify the various strata forming the solid crust of England and Wales by means of their fossil remains. There had been other and earlier collections of fossils, but to William Smith is due the credit of being the first to show that each bed of chalk or sandstone, limestone or clay, is marked by its own special organisms, and that these can be relied upon as characteristic of such stratum, wherever it is met with, over very wide areas of country. The fossils contained in this Cabinet were gathered together by William Smith in his journeys over all parts of England during thirty years, whilst occupied in his business as a Land Surveyor and Engineer, and were used to illustrate his works, 'Strata Identified by Organized

Fossils,' with coloured plates (quarto, 1816; four parts only published); and his 'Stratigraphical System of Organized Fossils' (quarto, 1817). A coloured copy of his large Geological Map, the first geological map of England and Wales, with a part of Scotland, commenced in 1812 and published in 1815—size eight feet nine inches, by six feet two inches wide, engraved by John Cary—is exhibited in the last Wall-case on the right hand side of this Gallery, at the north end. It is well worthy of careful inspection.

"William Smith was born at Churchill, a village of Oxfordshire, in 1769; he was the son of a small farmer and mechanic of the same name, but his father died when he was only eight years old, leaving him to the care of his uncle, who acted as his guardian. William's uncle did not approve of the boy's habit of collecting stones ('pundibs' = *Terebratulæ*, and 'quoit-stones' = *Clypeus sinuatus*); but, seeing that his nephew was studious, he gave him a little money to buy books. By means of these he taught himself the rudiments of geometry and land-surveying, and at the age of eighteen he obtained employment as a land surveyor in Oxfordshire, Gloucestershire, and other parts, and had already begun carefully and systematically to collect fossils, and to observe the structure of the rocks. In 1793 he was appointed to survey the course of the intended Somersetshire Coal Canal, near Bath. For six years he was the resident engineer of the canal, and, applying his previously-acquired knowledge, he was enabled to prove that the strata from the New Red Marl (Trias) upwards followed each other in a regular and orderly succession, each bed being marked by its own characteristic fossils, and having a general tendency or 'dip' to the south-east. To verify this theory he travelled in subsequent years over the greater part of England and Wales, and made careful observations of the geological succession of the rocks, proving also, by the fossils obtained, the identity of the strata over very wide areas along their outcrops. His knowledge of fossils advanced even further, for he discovered that those *in situ* retained their sharpness, whereas the same specimens derived from the drifts or gravel-deposits were usually rounded and water-worn, and had reached their present site by subsequent erosion of the parent-rock.

"In 1799 William Smith circulated in MS. the order of succession of the strata and imbedded organic remains found in the vicinity of Bath. His large Geological Map of England and Wales is dated 1815. On June 1, 1816, he published his 'Strata Identified by Organized Fossils,' with illustrations of the most characteristic specimens in each stratum (4to.). In 1817 he printed 'A Stratigraphical System of Organized Fossils,' compiled from the original geological collection deposited in the British Museum (4to.). In 1819 he published a reduction of his great Geological Map, together with several sections across England. These have just been presented to the Museum by William Topley, Esq., F.G.S.

"Mr. Smith received the award of the first Wollaston Medal and fund in 1831, from the hands of Prof. Sedgwick, the President of the Geological Society, 'As a great original discoverer in English geology, and especially for his having been the first, in this country, to discover and teach the identification of strata, and to determine their succession by means of their imbedded fossils.' In June, 1832, the Government of H.M. King William the Fourth awarded Mr. Smith a pension of £100 a year, but he only enjoyed it for seven years, as he died 28 August, 1839. In 1835 the degree of LL.D. was conferred upon Mr. Smith by the Provost and Fellows of Trinity College, Dublin. The highest compliment paid him was that by Sedgwick, who rightly named him 'the Father of English Geology.'

"The bust above the case which contains William Smith's Collection is a copy of that by Chantrey surmounting the tablet to his memory in the beautiful antique church of All Saints at Northampton, where his remains lie buried.

"We come next to a collection, the very name of which betrays the antiquity of its origin. It is known as 'Sowerby's Mineral Conchology.' This Collection was begun by Mr. James Sowerby prior to 1812, and continued by his son, Mr. James de Carle Sowerby, F.L.S., during the preparation of their great work entitled 'The Mineral Conchology of Great Britain,' which appeared in parts, between June, 1812, and December, 1845, and forms six volumes octavo, illustrated with 648 plates. The value of the work consists in the fidelity and accuracy of the figures given, and also that most of the specimens drawn are here named and described for the first time. They comprise fossils from all parts of England and from every geological formation. The small green labels mark the specimens actually figured in the work. The Collection was purchased by the Trustees from Mr. J. de Carle Sowerby, January, 1861.

"It may be interesting to record that many of the latter parts were illustrated by plates drawn by the late Mr. J. W. Salter, A.L.S., F.G.S., for so many years palæontologist to the Geological Survey. When a youth Salter was apprenticed to Mr. J. de Carle Sowerby, F.L.S., who was at that time both a naturalist and an engraver. The youthful apprentice afterwards married his master's daughter, and became, as is well known, one of the most brilliant palæontologists in this country.

"Another curious but small series represents the 'types' or 'figured specimens' of König's 'Icones Fossilium Sectiles.' This illustrated work on miscellaneous fossils in the British Museum was prepared by Mr. Charles König, the first Keeper of the Mineralogical and Geological Department, after its separation from the general Natural History Collections in 1825. The engravings are rough, but characteristic, and the first 'Century' (or 100 figures of fossils) is accompanied by descriptions; the plates of the second 'Century' have names only, but no descriptions are published with them.

"A far more important collection is that known as 'The Gilbertson Collection.' In 1836 Prof. John Phillips published Vol. ii. of his 'Illustrations of the Geology of Yorkshire,' which is devoted to the 'Mountain Limestone District.' In the introduction he writes as follows:—'My greatest obligation is to Mr. Wm. Gilbertson, of Preston, a naturalist of high acquirements, who has for many years explored with exceeding diligence a region of mountain limestone remarkably rich in organic remains. The collection which he has amassed from the small district of Bolland is at this moment unrivalled, and he has done for me, without solicitation, what is seldom granted to the most urgent entreaty: he has sent me for deliberate examination, at convenient intervals, the whole of his magnificent collection, accompanied by remarks dictated by long experience and a sound judgment.' He (Gilbertson) had proposed to publish a work on the *Crinoidea* himself, but his sketches as well as his specimens were all placed at Prof. Phillips's disposal. Phillips adds—'An attentive examination of this rich collection rendered it unnecessary to study minutely the less extensive series preserved in other cabinets. . . . Most of the figures of fossils are taken from specimens in Mr. Gilbertson's Collection, because these were generally the best that could be found.' The Gilbertson Collection was purchased for the British Museum in 1841.

"The collections which follow mark a distinct era in the annals of geological science. Some forty-seven years ago a little society was founded by a few London geologists, namely, Dr. J. Scott Bowerbank, F.R.S., Searles V. Wood, F.G.S., Prof. John Morris, F.G.S., Alfred White, F.L.S., Nathaniel T. Wetherell, F.G.S., James de Carle Sowerby, F.L.S., and Frederick E. Edwards, F.G.S., for the purpose of illustrating the Eocene Mollusca, and entitled the 'London Clay-Club.' They met at stated periods at each other's houses, and after a time they said, 'Why should we not illustrate all the fossils of the British Islands, and from every formation?' No sooner was this proposed than a society was founded, called the Palæontographical Society, in the year 1847 (just forty years ago). The first volume issued in that year was 'The Crag Mollusca,' Part I., Univalves, by Mr. Searles V. Wood, F.G.S. (with 21 plates). You have here before you the actual 'Searles Wood Crag Collection.' This collection was commenced in 1826, and occupied about 30 years in its formation. It represents the Molluscan fauna of the Red and Coralline Crags of the neighbourhood of Woodbridge, and from Aldborough, Chillesford, Sudbourn, Orford, Butley, Sutton, Ramsholt, Felixstow, and many other localities in Suffolk, and also from Walton-on-the-Naze in Essex. The specimens so collected were employed by Mr. Searles Wood in the preparation of his 'Monograph on the Crag Mollusca,' published by the Palæontographical Society (1848-1861); with supplements in 1871, 1873, 1879, illustrated by seventy-one quarto plates. Each figured specimen is indicated by having a small green label affixed to it. A geological description of the Crag formation by Mr. S. V. Wood, jun., F.G.S., and Mr. F. W. Harmer, was issued by the Palæontographical Society in 1871 and 1873. The collection was presented by Mr. S. V. Wood to the British Museum, January, 1856, and a supplementary collection was given by Mrs. Searles V. Wood in 1885.

"The next 'Palæontographical Collection' is of nearly equal antiquity and fully of equal merit. It is the Eocene Molluscan Collection formed by the late Mr. Frederick E. Edwards, F.G.S., about the year 1835, and was continually being added to until a few years before his death, which happened in 1875. It was acquired for the nation by purchase in 1873. Originally intending to illustrate the fossils of the London Clay, Mr. Edwards extended his researches over the Eocene strata of Sussex, Hampshire, and the Isle of Wight, where, assisted by Mr. Henry Keeping, he made the most complete collection ever attempted by any geologist, which still remains unrivalled. Mr. Edwards contributed six Memoirs to the Palæontographical Society, 1848-1856, also separate papers to the 'London Geological Magazine,' 1846, the 'Geologist,' 1860, and the 'Geological Magazine,' 1865, descriptive of the Eocene Mollusca in his collection. Mr. S. V. Wood continued the work for Mr. Edwards, describing and figuring the 'Eocene Bivalves' in the annual volumes of the Palæontographical Society for 1859, 1862, 1870, and 1877. Each specimen which has been figured is specially marked. About 500 species have been described and figured, but the collection is very rich in new and undescribed forms.

" The last Collection is that of a naturalist who devoted his entire life to the study and illustration of a single class of organisms, namely the Brachiopoda. It was formed by the late Mr. Thomas Davidson, LL.D., F.R.S., F.G.S., Vice-President of the Palæontographical Society (formerly of 9, Salisbury Road, West Brighton, and Muir House, Midlothian), between the years 1837 and 1886, with the object of illustrating his great work on the 'British Fossil Brachiopoda,' published by the Palæontographical Society, in six large quarto volumes, between the years 1850 and 1886, comprising 2,290 pages of text and 234 plates, with 9,329 figures, and descriptions of 969 species. Mr. Davidson was also the author of the Report on the recent Brachiopoda collected by H.M.S. 'Challenger' (Vol. i, 1880); of the article 'Brachiopoda,' in the Encyclopædia Britannica, Ninth Edition, 1875; of a Monograph of Recent 'Brachiopoda' (Trans. Linnæan Society, 1886 and 1887), and of more than fifty other separate Memoirs mostly bearing upon Brachiopoda both Recent and Fossil, printed in the Transactions and Journals of the various learned Societies, &c. His collection, both of Recent and Fossil Brachiopoda, together with all Dr. Davidson's original drawings, his numerous books and pamphlets, were presented by him to the British Museum, through his son William Davidson, Esq., Februa.y, 1886. By his direction the entire collection of recent and fossil species are to be kept together in one series, for the convenience of reference of all men of science who may wish to consult the same."

At the conclusion of Dr. Woodward's remarks Mr. William

Topley, F.G.S., kindly added some valuable information with reference to William Smith's maps and sections and his geological work in various parts of England.

The President then returned thanks to Dr. Woodward, and expressed the interest which, he said, he and all the Members present felt in this very important addition made to the exhibition-series of the Galleries devoted to Geology and Palæontology. After a further examination of the Collections the Members separated well pleased with their visit to this deservedly popular Museum.

VISIT TO THE DOULTON POTTERIES, AT LAMBETH.

WEDNESDAY, MARCH 30th, 1887.

Director: SIR HENRY DOULTON.

(*Report by* THE PRESIDENT.)

An exceptionally large party assembled at the show-rooms on the Albert Embankment, where they had an opportunity of inspecting a fine display of the artistic productions of Messrs. Doulton's works. A collection of the clays employed in the manufacture had been specially arranged for the information of the visitors, the proprietors having wisely assumed that geologists would be interested in the raw materials used in their ceramic industries. Sir Henry Doulton delivered an exceedingly interesting address, in which he traced the development of the art-industry at these works during the last twenty years, and explained the characteristics of the principal types of ware which they now produce. At the conclusion of his address, the Members were taken in small parties, each under a competent guide, through the workshops. There they had an opportunity of inspecting, under very advantageous circumstances, the entire process of manufacture, from the original raw material through every stage of manipulation until the finished object left the hand of the artist who impressed upon it the final touch.

It is well-known that certain Dutch potters settled at Lambeth as early as the middle of the seventeenth century, and there carried on the manufacture of delft. This ware, which took its name from Delft, in Holland—the original seat of its production, where its manufacture dates back to the fourteenth century—consists of a coarse earthenware body coated with a brilliant opaque-white tin-enamel, upon which designs, more or less crude, were painted, usually in cobalt-blue, though sometimes in manganese-purple and other tints. Good specimens of old Lambeth delft, in the form of wine-jugs (sack-pots), dishes, candlesticks, pill-slabs, &c., may be seen in the ceramic collection of the Museum of Practical Geology.

Not only did the early Dutch potters at Lambeth manufacture delft, but they also produced, towards the close of the seventeenth century, salt-glazed stoneware. It is said that, in 1680, a farm-servant in Staffordshire being engaged in boiling brine in a pipkin allowed it to boil over, and was surprised to find that the earthenware vessel, on cooling, exhibited a brilliant glaze wherever it had come in contact with the hot salt. This accidental discovery was soon utilized by the Staffordshire potters, while at Lambeth stoneware glazed with salt gradually came to be an established manufacture. Stoneware consists of a dense highly-vitrified body, not translucent like porcelain, but not absorbent like earthenware. The stoneware is glazed and fired at a single operation. When the ware is in the kiln at a high temperature—and a great heat is necessary to secure partial vitrification—a little common salt is thrown in ; this volatilizes and its vapour reacts with the materials of the ware, the sodium of the salt forming a coat of fused sodium silicate, which serves as a thin and brilliant glaze, while the chlorine of the salt forms with the hydrogen of the steam, which is always present, hydrochloric acid. Salt-glazed stoneware was the staple product of the Lambeth potteries up to a few years ago. Vessels of such ware, in consequence of their power of resisting the attack of acids, were in great demand at chemical works; and in 1846 Mr. (now Sir) Henry Doulton introduced the manufacture of stoneware pipes for drainage and other sanitary purposes, the impervious surface and imperishable nature of stoneware rendering it especially fitted for such work.

A new impulse was imparted to the Lambeth works about the year 1855 by Messrs. Doulton's introduction of the manufacture of terra-cotta or unglazed pottery, limited at first to garden vases, but afterwards extended to architectural medallions and various works of art. In 1866 Mr. George Tinworth entered Messrs. Doulton's employ, and his genius has gradually given to the Lambeth terra-cotta a world-wide reputation.

About sixteen years ago Messrs. Doulton turned their attention to the production of artistic stoneware, which soon acquired celebrity, due especially to the spirited designs of animals incised in the ware by Miss Hannah Barlow. Other modes of decoration were rapidly introduced ;. leaves, flowers, dots, discs, and borders were stamped in clay and sealed on the body; while colour was also introduced, though the high temperature necessary for firing stoneware renders the range of pigments very limited, and gives rise to great difficulty in producing definite tints. The production of this ornamental pottery, now known as " Doulton ware," offers employment to a large staff of female artists.

Of other art products which in recent years have characterized the Lambeth works, mention may be made of the *pâte-sur-pâte* on stoneware, the *impasto* on faience, and the body known as *silicon ware*, which is described as " an uncoloured body resembling both stoneware and jasper." The manufacture of most of these ceramic products was witnessed by the Members of the Association.

Since the production of all kinds of pottery and porcelain is primarily dependent on natural clays, the industry cannot fail to interest geologists who study the economic side of their science. During the excursions of the Geologists' Association the Members have frequent opportunity of observing the occurrence of different kinds of plastic clay in the field ; and on the occasion of their visit to Lambeth they had an opportunity of seeing these clays applied to purposes of use and ornament, ministering to the wants of man and contributing to his enjoyment.

EASTER EXCURSION, 1887.

PRELIMINARY EXCURSION TO SOUTHAMPTON.

(In conjunction with the Hampshire Field Club.)

Director : WILLIAM WHITAKER, B.A., F.G.S.

(*Report by* THE DIRECTOR.)

Members arrived at Southampton on Thursday evening, April 7th. On the next day they went by rail to Shawford, where they saw the lynchets, etc., of the Chalk Downs, and examined a pit in the uppermost part of the Chalk, with an abundant supply of *Holaster pillula*, and at top some pipes of clay, the filtrate from water that had sunk through the Chalk.

Before again descending into the valley of the Itchen attention was drawn to the features of the country: the dip-slope of the Chalk to the south; the wooded ridge of the Tertiary beds, which soon come on in that direction; and the rise of the Chalk to the north, with the prominent St. Catherine's Hill, near Winchester, encircled by a British earthwork.

The party then walked along the right bank of the Itchen, and saw the tufa-terrace, a mass of calcareous earth deposited by the river, but at a slightly higher level than the rest of the alluvium, and, therefore, not liable to floods. This tufa consists chiefly of carbonate of lime, and sometimes contains many land and fresh-water shells of recent species.

The new Southampton Waterworks having been reached, the Director described the site, close to the line of outcrop of the Chalk, in relation to the question of getting large supplies of water from the Chalk. He remarked that where a large supply was needed there were various points to be considered. Of course the works should be as near the town to be supplied as possible (having due regard to other points). They should be, however, as a rule, where the Chalk was not thickly covered by Tertiary beds, giving preference, indeed, to a site where it was bare or nearly so. They should be at a low level; away from sources of contamination; and so placed as to be at, or near, a point where the underground water-level is low, or, in other words, where that water tends to flow naturally. The site of these new works fulfils these requisites, being at the outcrop of the Chalk nearest to Southampton, besides having a railway alongside. The water-level is 20 feet down, and pumping, from trial-borings, showed that there was a large amount to be got. Further pumping, some time after the Excursion (done whilst fixing the permanent pumps), has shown an increase in the yield.

Mr. W. Matthews, the engineer, after welcoming the visitors on behalf of the Mayor and Corporation, described the works, which at present have two wells, six feet in diameter and 100 feet deep, in the uppermost part of the Chalk, here mostly very soft and with few flints. These wells were made throughout by boring,* and the water will be pumped from them to the softening-works, the largest in the kingdom (the process adopted being that of Atkins), and then forced up to the reservoir, on Otterbourne Hill. Mr. Matthews took the party through the works, as yet unfinished, and explained the engineering details.

---

* Only eleven days afterwards Mr. Matthews gave a detailed description of these wells to the Institution of Civil Engineers. See 'Proc. Inst. C.E.,' Vol. xc, pp. 33-39, plate 1.

Passing through Otterbourne a visit was paid to one of the pits in the sand which there forms the top part of the Reading Beds, that formation in this neighbourhood consisting generally of mottled plastic clay.

The Tertiary escarpment having been ascended, after drooping energy had been freshened by lunch, the new reservoir was reached. This had been lit up for the occasion, and each visitant was also furnished with a taper, so that, on descending, a strange, weird view was seen, the impressiveness of which was added to by the reverberating echoes, making it somewhat difficult for Mr. Matthews to explain the structure.

On again outcropping to daylight the Director remarked that the excavation for the reservoir had shown a most interesting and unique section, the Bagshot Pebble-beds resting somewhat irregularly on the sandy top London Clay, in the absence of the Lower Bagshot Sand. A rash offer of a bronze medal to anyone who could find anything else than a flint-pebble in these pebble-beds in the adjoining pit might have ruined the Director had its acceptance been insisted upon, as he had forgotten to provide himself with a supply of the medals in question, never dreaming that there would be so great a demand for them as occurred. It was strange, indeed, how the idea of reward stimulated geologists to find small quartz pebbles where none had been found before! No one, however, found an angular stone.

Tracks were then made southward, and a brickyard near Allbrook was visited, with pits in London Clay and in the sand of the Reading Beds. Thence, descending to a still lower level, the railway was reached, north of Bishopstoke Station, and a cutting, opened for ballast, was seen. This is in the gravel-flat of the Itchen, which must have been formed when the river was larger and swifter than now, and the land at a higher level. On the north, London Clay was seen beneath the gravel; whilst southward, Bagshot Sand came up in places along the lower part of the cutting. Farther south, a little brick-earth occurs over the gravel.

The return to Southampton was made from Bishopstoke, and in the evening the museum, art-galleries, and laboratories of the Hartley Institute were specially opened by the courtesy of the

Council. The visitors were received by the Executive Officer, Mr. T. W. Shore, who also described the collection, calling particular attention to flint implements found at and near Southampton, to some elephants' teeth from the local gravel, and to London Clay fossils from the outskirts of the town. A vote of thanks, proposed by the President, to the Council and to Mr. Shore was acknowledged by Mr. M. Miles and that gentleman.

On Saturday, the 9th, a start was made from Southampton by train to Netley, where, on arrival, about 9.30, the muster of the combined societies was found to number between 40 and 50. The day was almost wholly given up to the examination of the railway then being made from Netley to Fareham, and the following remarks on the sections along that line must be understood to refer to their state at that time, much work having been done since.

At the first convenient halting-place, the Director addressed a few words to the members of the Hants Field Club regretting the absence of their President, Prof. De Chaumont, and expressing, on their behalf, sympathy with him in his long-continued illness. Mr. Rudler then took the opportunity of supplying an omission in the proceedings of the day before (caused by the sudden and mysterious disappearance of Mr. Matthews) by expressing the thanks of the party to that gentleman for conducting them over the Waterworks and explaining the construction thereof.

At first, near Netley, the cuttings of the railway are in gravel, belonging to a high terrace of River Drift. Underneath this, however, the Bracklesham Beds, consisting of clays, loams, and sands, are soon touched. The gravel rests irregularly on these, showing in section a set of scoops or festoons. In one cutting the Director called attention to a "Prehistoric Ink Manufactory," alluding to a black layer in the gravel following the aforesaid junction, which was caused by water containing vegetable matter (from the soil) sinking through the permeable gravel and dissolving some of its iron-colouring, until stopped by the impermeable clay beneath, when the black matter, produced by the mixture of vegetable solution and iron-salt, was deposited.

Before reaching Bursledon the remains of an old saltern in Badnam Creek (Hamble River) were pointed out, and Mr. Shore gave a short account of the manufacture of salt in Hampshire, showing that this industry was of ancient date, 20 works in the county being mentioned in Domesday, and some in Hayling Island having been used in Roman times. The latest was in Newtown Bay, where salt was made in 1858. These works were always in estuaries, which the Director suggested was due to the facts that they would be less expensive in construction and less liable to destruction in such sites than by the open sea.

At Bursledon the Lower Bagshot Sand seems to rise up from beneath the Bracklesham Beds, but the junction could not be seen.

At this village, on the right bank of the Hamble, a good example was seen of the effect that is likely to result from making an embankment over soft alluvial beds. So yielding was the ground that the embankment had sunk as much as 20 feet, forcing the alluvial earth not only upwards, but also out into the tidal river-channel. It seemed likely that the embankment would have to be abandoned and some sort of viaduct made instead.

Mr. Shore here spoke of the remains of the Danish galley that had been found in one of the creeks on the other side of the river, and was still to be seen at low water of spring-tides.

At the viaduct over the Hamble the Director gave the word "Engineers and such-like to the front," and handed over the resultant select committee to Mr. Anderson, the contractor's engineer, who kindly took the temporary secessionists over the work and explained its construction. In driving one of the cylinders many nuts were found in the marsh-clay beneath the river.

There being nothing to see just east of the Hamble River a short cut was made which conveniently led through the brickworks north of Sarisbury Green, where a good section of London Clay with fossiliferous septaria was seen on the south, and on the north a junction of that formation (with a pebbly base) and the sand of the Reading Beds.

The party returned to the railway, a little to the eastward ; but little was to be seen until reaching a small cutting more than three-quarters of a mile east of Sarisbury, which showed a junction of London Clay and Reading Beds much like that of the brickyard.

Some way beyond this begins a long cutting, not then open throughout, but which will reach to the Titchfield Valley. At first a thick deposit of gravel was seen over the Bagshot Sand, the former containing, in its bottom part, included masses of the latter, so that care is sometimes needed to fix the junction. Higher up, south-eastwards, clayey Bracklesham Beds come on beneath the gravel; and farther on the junction of the former with the Lower

Bagshot Sand, marked by a thin pebbly bed at the base of the Bracklesham Series, was seen for some distance until the sand alone occurs beneath the gravel. The farther end of the cutting was in the base of the Bagshot Sand, just reaching, at last, to the sandy top London Clay, and much water flowed out here, so that a miniature cañon was formed in the sand at one side, ending in a little water-fall. The rise of underground water-level in a permeable bed as one goes into a hill away from springs was also shown on a small scale. This part will have to be deepened.

Descending into the Titchfield Valley, which the line will cross by a huge embankment, an unusual opportunity was afforded for inspecting a section in a river-bed laid open in the works for the culvert under the railway. Marsh-clay and peaty earth with stumps of trees in places was seen, and some pieces of Samian ware were found which were afterwards given to the Hartley Institution. Beneath was a little irregular gravel, and then the London Clay was touched.

The Director drew attention to the tips being made for the embankment on the eastern side of the river, in order to use them in illustration of the theory that the position of one deposit next above another did not always prove that the whole of the upper deposit was newer than the lower one ; the processes of deposition may have gone on together, though successively. The cutting from which came the earth that was being tipped consisted of London Clay with layers of septaria, some of which were large masses, and all more or less round. It followed, therefore, that on a truck-load being tipped the heavy roundish stones rolled down the slope to the bottom, ahead of the more broken-up, more sticky, and more irregular-shaped lumps of clay, as was appropriately shown at the moment of discourse by some stones rolling down towards the comfortably seated party, the largest of them going for the Director, and just succeeding in reaching the truck on which he rested, without, of course, disturbing him. This process going on continuously the geologist of the future, in making a section of this embankment, would find a layer with big stones along the base and little else than clay above. If, however, he concluded that the stone-bed was everywhere the older deposit he would go wrong, for that part of it in the deeper and newer-formed part of the bank was deposited after even the top of the overlying clay at the shallow landward end. That the stone bed is older than the immediately overlying clay is all that can be said. It was from such reasons that Godwin-Austen had suggested that Upper Greensand was not all newer than all Chalk ; but that the former might be the shore-deposit of the latter.

On going eastward into the next short cutting, the occurrence of a piece of ironstone in the clay gave Mr. Shore the chance of referring to the old ironworks at Fontley near by.

The cutting just eastward will be a long one ; but its western part was almost all that was to be seen. This, however, was of considerable interest, for the more or less sandy London Clay contained many, though mostly very fragile, fossils ; the discolouration of the upper part, from dark grey to brown, by peroxidation of the ferruginous colouring-matter, was plainly seen, and Londoners were probably much astonished at the occurrence of two continuous pebble-beds, each about a foot thick, in the midst of their own particular clay, no such occurrence having been noted in the London Basin. These beds consisted of flint pebbles with fossils (chiefly oyster-shells) in a loamy matrix ; they were about two feet apart, and in one of them Mr. E. Westlake found a specimen of a large *Terebratula*, the first of its sort in the formation ! This turned out to be *Terebratula bisinuata*, a species that has very rarely been found in Barton and Bracklesham Beds, though plentiful sometimes in the Calcaire grossier of France. Since the excursion a great number of specimens have been found by Messrs. Westlake, W. Dale, J. W. Elwes, Shore and Whitaker. They seem to occur in nests like miniature mussel-banks.

Then the two societies parted, the Hants folk making their way homewards, whilst the detachment of the Association firstly had tea at Fareham, and then went on by rail to Bognor, where the Members stormed the Norfolk Hotel and were made comfortable by Mr. Barber.

The next morning, whilst some Members remained at Bognor, the greater number drove out to Pagham Church, close to which is the site of a palace, formerly belonging to the Archbishopric of Canterbury, and in the afternoon found themselves at Selsea, still under Mr. Whitaker's guidance. The chief object of this visit was to see the extraordinary coast-changes that have taken place. There are records of great loss of land along this coast, from the cutting-back of the very low cliffs (if that name can be used for such slight features) and the driving inwards of the beach by the sea. Selsea was formerly the head-quarters of the Bishop's See, since removed to Chichester, the anchorage still known as "The Park" marking the site of former land. The most interesting change, perhaps, is also the latest, having occurred since the new Ordnance Map was made (1875). On the old Ordnance Map, on the scale of an inch to the mile, made many years ago, the entrance to Pagham Harbour is shown as half-a-mile due south of the church, and it is known that at still earlier times it was further south-westward (towards Selsea). On the new Ordnance Maps (25 inches and 6 inches to the mile) this entrance is shown as more than half-a-mile east of the church, a shift north-eastward of about three-quarters of a mile. This north-easterly shifting of the entrance has been brought about by the gradual pushing forward of the shingle ridge in that direction, by reason of the general set of the currents along the coast being from west to east. When the entrance was pushed eastward of Pagham it became a narrow channel near to and parallel with the low coast, and the continuance of the change has led, of late years, to the total extinction of the channel, the power of the tidal stream on the land side having become unequal to cope with the powerful action of the sea in piling up shingle, so that at last the shingle has swept, in a continuous mass, across the channel. From this it has come about that what was formerly Pagham Harbour, with a spread of water at high tides about 1½ miles long, by from half-a-mile to a mile broad, is now dry marsh-land, the extent of reclaimed land being about 750 acres, across which the water of the small stream now finds its way to the sea by a sluice through the shingle.

The sea has therefore exercised what may be called an automatic closure against itself, cutting off its tidal access inland by its own beach. Politicians might perhaps note this process with profit. From this gradual shifting of the entrance one is entitled to reason backwards, and to infer that, like conditions having held, the entrance must have been at the southern point of the harbour, whence it would gradually move northwards by the increase of shingle from Selsey Bill. On reaching the north-western edge of the marsh, the Director pointed out what he thought to be good evidence of the entrance having once been in such a position. Near what remains of the old Selsea Church the party rested on the old earthwork, of which, alas, but half is now left. The Director here put it to the Members whether they were inclined to consider their remote predecessors in the land as idiots, a question that met with a negative, both unanimous and instantaneous, it being held to be impossible that any process of development could lead to the evolution of geologists from such a race. He then remarked that no people who were not idiots would have made such a fortification without an object. A fort is meant to command something, and as things now are this fort would command nothing, for on the western side there is a tolerably perfect flat, at the same level as the earthwork, and on the eastern side only the marsh, at a slightly lower level, which, but a few years ago, was covered by shallow water at high tide only. He suggested that the only possible object for such a work was to command the entrance to the harbour, and he inferred, therefore, that when the fort was made the deep-water channel into the harbour must have been close by, so as to pass by the eastern side of the fort. From the round shape of the fort, and from the character of what remained of the work, it seemed likely that it was of British age ; but whether it is British, Roman, mediæval, or modern matters not to the general deduction. Given the age of the fort, we have the date when the channel into the harbour flowed close by. The church, which is of Early English character, seems to have been built on ground that must once have formed part of the "intrenchment," as it is cautiously named on the Ordnance Map (without any attempt to fix its date).

At Selsea village the collection of Bracklesham fossils made by Mr. Woodland was examined, and many specimens were procured therefrom. At the Bill the Director remarked that this name was given to parts of the coast which projected beyond the rest, and he alluded to the fact that, even on paper, bills were prominent objects, often, indeed, too much so. The name, too, in its uncontracted form, is conspicuous in our history, as evidenced in early times by William the Conqueror, in later times by the Divine William, and in the present day by the People's William. Moreover both the late and the present Presidents of the Geologists' Association gloried in the name, and the party was then under the guidance of one who was not ashamed to bear it. He then noticed that from the low flat nature of Selsea (a tract consisting of a thin loam or brickearth, beneath which gravel was seen here and there) one was at first puzzled to understand how it could have withstood the ravages of the sea at all. The explanation of the occurrence of the Bill lay in the fact that in the Bracklesham Beds, which were laid bare at low tide, there is a thin bed of foraminiferal limestone, forming an extensive ledge, and hard enough to break the onslaughts of the sea. Specimens of this bed had been found plentifully on the Pagham beach earlier in the day.

On the return, along the coast of Selsea, the shingly gravel beneath the brickearth was seen, and the Director remarked that this gravel, which contained marine shells in places, seemed to be continuous with the gravel of Portsmouth, etc., which was a river-gravel; and he suggested that they had here reached the tract where the former river had joined the sea. The height of the tide prevented any examination of the Bracklesham Beds, but the great amount of glauconite grains, derived therefrom, in the sand of the beach, was noticed.

EXCURSION TO BRIGHTON AND NEWHAVEN.

EASTER MONDAY AND TUESDAY, APRIL 11TH AND 12TH, 1887.

Directors: H. WILLETT, F.G.S., AND W. TOPLEY, F.G.S.

(*Report by* W. TOPLEY.)

The party met at the Free Library and Museum on Monday morning, and were received by Mr. E. Crane, Chairman of the Museum Committee, Mr. Lomax, the Curator, and by Mr. Pankhurst. Hon. Sec. of the Brighton Nat. Hist. Soc. After a short time spent in examining the Museum, and in enjoying the luncheon, kindly provided by Mr. Willett, the party started along the cliff eastwards, making its first halt at the large groyne at the east end of the town. Descending to the shore an examination was made of the ancient beach and overlying "Elephant Bed" or Coombe Rock. The beach (composed of rounded flint shingle, and exactly resembling the modern beach) lies eight or ten feet above the present high-water mark. The old beach was formerly exposed at many places along the shore, but west of this point it has been built over by the sea-wall, and to the east the cliffs are rapidly wearing back by the action of the sea, thus destroying the old beach. The action of the sea on the coast was here explained, and the influence of groynes pointed out. The shingle along this coast, under the influence of the prevailing south-westerly winds, travels from west to east. Groynes are run out at right angles to the shore, or nearly so, which arrest the shingle. When a succession of groynes are constructed, as is the case along the front of Brighton, the shingle accumulates and protects the shore, or would do so if allowed to travel; but the shingle is, to a large extent, stopped at Worthing by excessive groyning, and again at Shoreham Harbour, so that the full supply is not received at Brighton. The large groyne at the Black Rock, at the east end of Brighton, is constructed to catch as much shingle as possible, consequently very little shingle passes on to the east, the cliff is robbed of its natural protection and is rapidly wasting away.

The Coombe Rock above the old beach has given rise to much discussion. It is composed mainly of weathered chalk, but contains some layers of loam, sand, and dirty gravel. It is apparently well stratified in places, and when seen in section, looking east or west, is often strangely contorted. These contortions are less evident when looking along the cliff face. It contains land shells and mammalian remains, chiefly of elephant—whence its name of "Elephant Bed." By some it has been considered to be a subaqueous deposit, by others as formed by subaërial action. Mr. Clement Reid has recently discussed the question,* and he considers the Coombe Rock to have been formed at a time when the Chalk area north of it was perpetually frozen beneath the surface, and was therefore impervious to water. The winter's snow would melt in summer, and the water being unable to percolate through the chalk, would drain rapidly down the dip-slope to the south, carrying chalk *débris* with it.

From the Black Rock the walk was continued along the top of the cliff to Rottingdean. Here, again, there are groynes, built to collect the shingle.

On returning to Brighton the party again collected at the Museum, and were then joined by Mr. Willett, who described his fine collection of Chalk fossils, chiefly from the Brighton and Lewes districts. Dr. G. J. Hinde made some remarks on the flints and sponges from the Chalk, in which the collection is rich. The large collection of cores and fossils from the Sub-Wealden boring was then referred to; and the general arrangement of the Museum was described by Mr. E. Crane, F.G.S.

---

* "On the Origin of Dry Chalk Valleys and of Coombe Rock." 'Quart. Journ. Geol. Soc.,' Vol. xliii, p. 364.

Tuesday.—The party started by train for Newhaven, where they were met by the Harbour Master, Capt. R. G. White, R.N., who kindly took the train on to the harbour and then conducted the Members over the new works, carried out under the direction of Mr. A. E. Carey, M.Inst.C.E. A breakwater (which is to be 2,800 feet long) is being carried from under the Castle Hill on the west side of the harbour, and is built of bags of concrete, each weighing 100 tons. The old mouth of the Ouse, until the time of Queen Elizabeth, was under Seaford Head, 2½ miles east of the present outlet, it having been driven eastwards by the travel of shingle from the west. The old course of the river can still be seen behind the sea-wall, extending from Newhaven to Seaford. As the breakwater is extending the local tides are altering, and shingle is accumulating on the east of the harbour mouth. Shingle does not accumulate to any great extent on the west side of the breakwater.*

Some members of the party climbed the Castle Hill to examine the Tertiary outlier, the best exposure of the lower Tertiary beds in Eastern Sussex. The section has been several times described, successive writers giving fuller sections as the cliff was gradually cut further back. The earliest account, by Webster, in 1814, gave only part of the Woolwich and Reading beds; a capping of London Clay is now seen.†

Again taking train, the party was conveyed to Seaford. Proceeding to the shore and then turning eastwards, the lowest Eocene beds were seen lying upon the Chalk with a rather steep southerly and south-westerly dip. Ascending the cliff, the walk was continued as far as the River Cuckmere, where the deflecting influence of travelling shingle upon a river mouth can be well studied. The shingle carries the outlet eastwards, and an artificial cut is made to let out the water.

The absence of Mr. Willett from the party in the field was much regretted, but he had with much forethought made all necessary arrangements, and had most generously provided a luncheon at Newhaven and a meat tea at Seaford.

---

* These particulars are taken from descriptions on the spot by Capt. White and from a paper by Mr. Carey—"Harbour Improvements at Newhaven, Sussex." 'Proc. Inst. C. Eng.,' Vol lxxxvii, p. 92, Plates 3 and 4; 1887.

† A full description is given by Mr. Whitaker, 'Quart. Journ. Geol. Soc.,' Vol. xxvii, p. 263; 1871.

REFERENCES.

Ordnance Survey Maps. New Series. 1s. each. Sheet 317, Chichester and Arundel; 318, Brighton; 319, Lewes; 332, Selsea.

Geological Survey Maps. 8s. 6d. each. 5, Lewes; 9, Brighton, Chichester, and Selsea.

——— Horizontal Sections. Sheet 76, Brighton northwards; Sheet 77, Newhaven, Lewes.

1833. G. MANTELL.—'The Geology of the South-East of England.' 8vo. London.

1854. J. PRESTWICH.—"The Woolwich and Reading Series." 'Q. J. G. S.,' Vol. x (Newhaven), p. 81.

1856. *R. A. C. GODWIN-AUSTEN.—"On the Newer-Tertiary Deposits of the Sussex Coast." 'Quart. Journ. Geol. Soc.,' Vol. xiii, pp. 40-72.

1858. *J. PRESTWICH.—"On the Westward Extension of the Old Raised Beach at Brighton." 'Q. J. G. S.,' Vol. xv, pp. 215-221.

1862. "Report of the Excursion to Lewes." 'Proc. Geol. Assoc.,' Vol. i (No. 9), pp. 274-277.

1871. W. WHITAKER.—"On the Cliff-sections of the Tertiary Beds . . . at Newhaven." 'Q. J. G. S.,' Vol. xxvii, p. 263.

1871. H. WILLETT.—'Catalogue of the Cretaceous Fossils in the Brighton Museum.' 8vo. Brighton.

1873. "Report of the Excursion to Brighton." 'Proc. Geol. Assoc.,' Vol. iii (No. 6), pp. 239-240.

1873 and 1877. J. HOWELL.—"On the Geology of Brighton." 'Proc. Geol. Assoc.,' Vol. iii (No. 4), pp. 168-188, and Vol. v (No. 2), pp. 80-90.

1875. W. TOPLEY.—"The Geology of the Weald." [Mem. Geol. Survey.] 8vo. Lond. [pp. 227-263.]

1878. F. DIXON.—'The Geology of Sussex . . .' 2nd Edit. by T. R. Jones. (Geol. Map of Sussex, 4 miles to 1 inch, by W. Topley.)

1882. A. HAVILAND.—'The Health-Guide Map for Brighton.' (Scale, 9 inches to 1 mile.) With Text.

1887. C. REID.—'On the Origin of Dry Chalk Valleys and of Coombe Rock." Abs. 'Proc. Geol. Soc.' for Feb. 23rd.

☞ The Papers marked * are reprinted in this work.

EXCURSION TO WHETSTONE AND FINCHLEY.

SATURDAY, APRIL 23RD, 1887.

Directors: H. B. WOODWARD, F.G.S., AND J. G. GOODCHILD, F.G.S.

(*Report by* THE DIRECTORS).

On arriving at Totteridge Station the party was conducted to a pit south of Whetstone where a small outlying mass of Boulder Clay was seen resting on the "Middle Glacial Sands and Gravels."

Mr. H. B. Woodward pointed out that this Boulder Clay was a portion of the chalky Boulder Clay that covers a large area in the eastern counties. It was composed mainly of Chalk and Flint, and also of the Jurassic Clays (Lias, Oxford and Kimeridge Clays). Fragments of oolitic limestone were comparatively rare, but it must be remembered that over a considerable tract to the north-west the Oxford and Kimeridge Clays come together without the intervention of the Corallian limestones. The late Mr. N. T. Wetherell, of Highgate, made a large collection of British fossils from the Boulder Clay of the neighbourhood, especially from a pit at Muswell Hill; and the greater part of this collection is preserved in the Museum of Practical Geology.

The Boulder Clay in Mr. Woodward's opinion was a product of land-ice, and he observed (speaking from experience in the eastern counties) that the accumulation rarely exhibited any appearances of stratification. In many places there was a streaky structure that simulated stratification, but this was evidently due to pressure. As observed by Mr. Clement Reid in the Holderness region,* shells are sometimes found in Boulder Clay, crushed, but with the fragments only separated by a small interval, and these may frequently be fitted together. As a rule the beds beneath the chalky Boulder Clay in the eastern counties are more or less contorted, and in the pit now visited there was evidence of some disturbance in the underlying beds.†

The party then walked, through Finchley, to the pit in Somers Lane, where the Boulder Clay is being worked into bricks. On the north side of the pit the cutting had lately been newly bared for a length of thirty yards or so, and a continuous face of rock, about six feet in height, was exposed. In the middle of the section the upper four feet consisted of the ordinary Boulder Clay of the district; but beneath that, for a length of twenty yards or more, the section showed bands of striped loams, loamy clays, and sands, alternating with, and passing horizontally into, Boulder Clay like that above. In another face of the same pit the local base of the Boulder Clay was seen lying upon the sands and gravels that here usually occur beneath. In this case there were signs of gradation from the one type to the other. From the Boulder Clay *in situ* the party obtained many specimens, including representatives of the Red Chalk, Carstone, various Jurassic rocks, New Red Sandstone and breccias, various rocks of Carboniferous age, rocks from Charley (or Charnwood) Forest, and a few representatives of granite and metamorphic rocks, apparently foreign to the British Isles. From some heaps of stones got out of the Boulder Clay by the workmen larger blocks of some of these same rocks were obtained, and amongst them were some basic rocks, undistinguishable, macroscopically, from the Whin Sill of the North of England. There were also some other basic rocks regarded as of Scandinavian origin.

---

* 'Geology of Holderness' (Geol. Survey, p. 16).

† See H. B. Woodward, 'Proc. Geol. Assoc.,' Vol. ix, p. 111; and 'Geology of England and Wales,' Ed. 2, p. 506.

After the party had concluded their search Mr. Goodchild spread out a map of the British Isles and laid upon it, each in its relative position, fragments of the various erratics gathered from the drift there. After calling attention to the remarkable radial dispersion of the boulders originating at each of the centres represented, and to the resulting convergence, at any given spot, of boulders primarily derived from sources widely separated, he went on to make some observations upon the origin of the Finchley Boulder Clay. Its present extension he regarded as marking, very nearly, the southernmost limit of the ice sheet—the rate of melting of the ice-fringe hereabouts having exactly balanced the supply. He considered the Finchley Boulder Clay as being approximately of the same age as that originating when the Shap Granite, &c., was transported inland and uphill over Stainmoor—that is to say, as being contemporaneous with the period of maximum glaciation, when Scandinavian land-ice on the one side, and the North Atlantic ice on the other, reinforced our glaciers and hemmed in our local ice so that it was compelled to flow southward beyond the limits it would otherwise have attained. In every essential point, down to minor points of detail, the Finchley Boulder Clay agreed with the Boulder

Clays of this age in the North of England, and he considered it had probably originated in the same manner. He regarded it, and all the various stratified beds associated with it, as the sediment, representing the mud and stones that had worked up into the ice from various parts of the areas its feeders had traversed, and that had been liberated, in its present various forms, by the melting of the ice, under subaerial conditions, immediately after the climax of the Glacial Period. This view would serve to account for the otherwise puzzling association of Boulder Clays devoid of bedding with other strata obviously arranged by the action of water, as in the present case. It would also serve to account for the presence of marine organisms in high-level deposits of glacial origin.

In explanation of the occurrence of erratic blocks from Scandinavia, Mr. Woodward remarked that while the Lower Boulder Clay of Norfolk was characterized by fragments of eruptive rocks, many of which were probably derived from areas situated to the north-east, the Upper, or Chalky, Boulder Clay was for the most part made up of detritus from the north-west. At the same time the newer deposit may have been, in part, formed from the older drift ; hence erratics from distinct areas would be commingled in this deposit.

Among the fossils observed were :—*Gryphæa dilatata*, *Belemnites abbreviatus*, *Lima gigantea*, *Discina latissima*.

Mr. Rudler, in returning thanks, drew attention to the labours of Mr. Henry Walker, and remarked on the presence at this excursion of one of the founders of the Association, Mr. George Potter.

A few Members subsequently visited the Highgate Literary and Scientific Institution, where a number of fossils, collected principally by the late Mr. N. T. Wetherell, from the London Clay and the Drift of Highgate, Muswell Hill, and Finchley, are preserved.

REFERENCES.

Geological Survey Maps, 7 (Drift Edition), and 'London and its Environs.'

PROF. MORRIS.—"Note on the Gravel Beds of Finchley." 'Geol. Mag.,' v (1868), p. 411.

W. WHITAKER.—'Guide to the Geology of London.' 4th Edition. 1885.

HENRY WALKER.—"The Glacial Drifts of North London." 'Proc. Geol. Assoc.,' ii, p. 289. 1870. "Report of Excursion to Hendon and Finchley." 'Proc. Geol. Assoc.,' iii, p. 115. "Report of Excursion to Finchley." 'Proc. Geol. Assoc.,' iii, p. 214. "The Glacial Drifts of Muswell Hill and Finchley." 8vo. Lond. 1874.

EXCURSION TO THE BRENT VALLEY, DOLLIS HILL, AND HAMPSTEAD.

SATURDAY, MAY 7TH, 1887.

(In conjunction with the Middlesex Natural History Society.)

Director: J. LOGAN LOBLEY, F.G.S.

(*Report by* THE DIRECTOR).

On the party assembling at Neasden, it was pointed out that the portion of Middlesex about to be traversed is characterized (1) by its undulating or hilly character; (2) by its great verdancy or greenness; (3) by its being well-wooded, and having oaks for its prevailing trees. All these characters are due to its geology, being the direct result of the area being formed of the London Clay, which is well adapted for the growth of the oak, and forms land better suited for pasturage and hay than for arable purposes, while the erosion of the Clay has formed the valleys and given the gentle slopes and outlines of the elevations. These characters, while not producing grand features in a landscape, yet afford in Middlesex some lovely scenery, and give from several elevated points extensive and very beautiful prospects.

After descending the south-eastern slope of the pretty valley of the Brent, lighted up by the gleaming waters of its beautiful lake, and adorned by the white spire of Kingsbury Church rising from the wooded slopes on the opposite side, the geologists were soon again assembled, but now on a bed of gravel, close to the river, forming the lowest part of the valley. The Director explained that the Brent Valley, subsidiary to the greater valley of the Thames, with which for some distance it runs roughly parallel, has a length of about ten miles. The little river rises in the parishes of Finchley, Hendon, and Hampstead, and after running through the parishes of Kingsbury, Willesden, and Perivale, turns south, and enters the Thames at Brentford. The gravels form part of the alluvial deposits brought down by the Brent in the past, and are not confined to the lowest level of the valley, but are also seen on the level of Kingsbury Church, at an elevation of 60 feet above the stream, thus giving a low-level and a high-level gravel, attesting the different heights of the bottom of the valley at different periods. In this respect the Brent Valley is comparable with the main Thames Valley, which also displays gravels at different elevations. The Brent gravels are, however, dissimilar to the Thames gravels in not being so ferruginous, as well as being otherwise differently composed. The Thames gravels consist of subangular flint fragments derived from the erosion of chalk lands, while the Brent gravels consist of whole or broken rounded flint pebbles, together with some quartz pebbles and fragments of other rocks. Out of 821 stones examined by the Director, 221 were rounded flint-pebbles unbroken, 549 were broken flint-pebbles, while 30 were quartz, and 21 were fragments of granitic rocks. These, derived from the previously existing gravelly drift-deposits of the Brent's upper waters, indicate the source of these deposits, which were derived from Lower Eocene, Cretaceous, Oolitic, and Liassic, and even from Igneous rocks. The granitic fragments contain hornblende, evidence that they were originally derived from Leicestershire, where, in Charnwood Forest and at Mount Sorrel, hornblendic granite is now quarried for road material for our London streets. It was thus shown that a bed of gravel, even if it do not yield organic remains, may be of great geological interest.

The present small stream of the Brent was followed for a little distance, and then crossed at the site of an ancient ford; and after ascending the valley slope and reaching Kingsbury Church, the party passed through the churchyard, and collected around an exposure of the upper-level gravels, which are seen to be quite similar to those at the lower level. The position afforded a fine view of characteristic London Clay scenery, this part of Middlesex being as yet quite untouched by the extension of the metropolis, and as sparsely inhabited as it was two hundred years ago. It is, indeed, much less inhabited than it was fifteen hundred years ago, for here were situated British and Roman camps, and a Roman and a Saxon town. Of the latter the church remains, one of the oldest churches in England, built mainly of large flints with some Roman bricks from the neighbouring ruins of a Roman town, of which a memorial still remains in the name of the adjacent Salmon Street. A visit was paid to the interior of the church, facilities for the examination of which were afforded by the Vicar, the Rev. James R. Mills, M.A.

The valley of the Brent was then recrossed by the embankment of the great Brent Reservoir, and the beautiful green slopes of Dollis Hill, overlooking this fine sheet of water, were traversed, and all again re-assembled on the summit of the hill, which commands an extensive view over a large part of the county, and from which can be seen the general configuration of the district. Maps were spread on the ground, and the Director, after calling Dollis Hill the Righi of Middlesex, pointed out that it was a ridge between two parallel valleys, two of a series of vales separated by elevations having a general parallelism, and an east and west direction This series of vales, with the intervening elevations, extends from the Thames northwards to the northern boundary of the county formed by the heights of Stanmore Heath and Harrow Weald, and other elevations then in view. But in addition to this series of parallel ridges there are two great hill-masses, standing distinct, and affording excellent examples of hills of circum-denudation. These are the hill-mass of Hampstead and Highgate to the east, and that of Harrow to the west. These two hill-masses rise to a height of over 400 feet, and retain on their summits remnants of the great sheet of Bagshot Sands* which in Eocene times overspread the whole of the district, and extended to the main mass of the formation at the west of Surrey. The great Thames Valley in the neighbourhood of London, and the whole of the subsidiary valleys, have been excavated out of the London Clay by the continuous, though unequal, action of water erosion. The elevations between the valleys are frequently found to be capped by other deposits of gravels and drifts, some of undoubted Glacial origin, as at Finchley, and some, as at Stanmore and Dollis Hill, of doubtful origin and age; but most probably these "Pebble-Gravels" and "Hill" or "Plateau" gravels, as they have been named by Mr. Whitaker, are some of Pre-Glacial, or Early-Glacial, and some of Mid-, Late-, or Post-Glacial age. A special excavation had been made in the grounds of the Earl of Aberdeen to show the character of the deposit on Dollis Hill, which was seen to consist chiefly of sand, with flint pebbles, a minority being unbroken and rounded, and a majority broken. From an examination, by the Director, of 675 stones it was found that 198 were unbroken, 476 broken, and only one proved to be of quartz, while there was not one granitic fragment.

Dollis Hill was now rapidly descended, and crossing the Edgware Road on the line of the Roman Watling Street, which runs north-westwards through a transverse valley, the party continued along the south side of the upper valley of the Brent for some distance, and then paid a visit to the newly-constructed Hendon main-drainage works, the special features of which were pointed out, and the system described, by Mr. Stockpole, the clerk of the works, under the direction of Dr. Hicks, F.R.S., of the Hendon Local Board, and Vice-President of the Geologists' Association.

---

* For these Prof. Prestwich now proposes the name "London Sands."—Ed.

Somewhat level ground was then traversed by way of Golder's Green to the northern slope of Hampstead Hill, where the Upper Sandy London Clay, characterized by abundance of *Voluta nodosa* and *Pectunculus decussatus*, makes its appearance by the road-side. The Heath was soon gained, when the Bagshot Sands were seen to form all the higher ground. The line of junction with the Upper Sandy London Clay forms a great bay, opening to the north-west, and enclosing lower ground, in which is situated the "Leg of Mutton Pond," its waters held up by the normal London Clay, which appears at the lower end, and beyond is cut into by a beautiful example of a valley of erosion, through which wanders an affluent of the Brent. The former bed of the feeder of the pond, or uppermost portion of this tributary of the Brent—now, unfortunately, running out of sight in drain-pipes—was traced to its commencement, and a good example on a small scale of the source of a river was seen in the boggy ground, with pools of water, consequent upon the issue of the rain-water, which had percolated through the summit sands, at their junction with the underlying argillaceous deposit. The obliteration of a very pretty natural feature by the Board of Works has quite unnecessarily destroyed what might have served for the instruction in physical geology and geography of future generations of Londoners for all time, while some interesting plants and animal organisms have been extirpated.

The Bagshot Sands were then passed over, to the summit of the Heath, from which radiate the descending valleys which so picturesquely sculpture the hill, and through which the issuing waters of the summit sands flow, forming in olden times the head waters of the Fleet, the Aye Bourne, and one of the tributaries of the Brent.

The geology of Hampstead was subsequently described, and after the thanks of the party had been eloquently proposed by the President, and responded to by Mr. Lobley, the day's proceedings terminated.

REFERENCES.

Geological Survey—Map, 'London and its Environs,' Sheet 7 (Drift Ed.).
„ „ Horizontal Section, Sheet 79.
„ „ 'Memoirs,' Vol. iv, "London Basin," by W. WHITAKER.
„ „ 'Guide to the Geology of London and the Neighbourhood,' by WILLIAM WHITAKER, B.A., &c.
"Reports of Excursions to Hampstead," 'Proc. Geol. Assoc.,' Vol. iii, p. 67; Vol. iv, p. 155; Vol. v, p. 160.
"On a New Section of the Upper Bed of the London Clay," by C. EVANS. 'Proc. Geol. Assoc.,' Vol. ii, p. 283.
"On the Geology of Hampstead," by C. EVANS. 'Proc. Geol. Assoc.,' Vol. iii, p. 21.
"On the Thickness of the London Clay," &c., by J. PRESTWICH. 'Quart. Journ. Geol. Soc.,' Vol. x, p. 415.
"On the Boring through the Chalk at Kentish Town," by J. PRESTWICH. 'Quart. Journ. Geol. Soc.,' Vol. xii, p. 124.
"On some of the Fossils of the London Clay," &c., by N. T. WETHERELL. 'Phil. Mag.,' Vol. ix, p. 462.
"On *Ophiuræ* found at Child's Hill," &c., by N. T. WETHERELL. 'Proc. Geol. Assoc.,' Vol. i, p. 417.
"On the London Clay of Highgate Archway," by N. T. WETHERELL. 'Proc. Geol. Assoc.,' Vol. i, p. 406.
"On a Well on the South Side of Hampstead Heath," by N. T. WETHERELL. 'Trans. Geol. Soc.,' Ser. 2, Vol. v, p. 131.
"On the Pebble Beds of Middlesex," by S. V. WOOD. 'Quart. Journ. Geol. Soc.,' Vol. xxiv, p. 464.
"On the Hydrographical Basin of the Thames," by Rev. W. D. CONYBEARE. 'Proc. Geol. Soc.,' Vol. i, p. 145.
'The Topography and Natural History of Hampstead,' by J. J. PARK (1818).
'View of the Agriculture of Middlesex, Soils, Wells,' &c., by J. MIDDLETON (1807).
"Description of Kilburn Wells," by J. G. SCHWIESSE. 'Phil. Trans.,' 1792, p. 115.

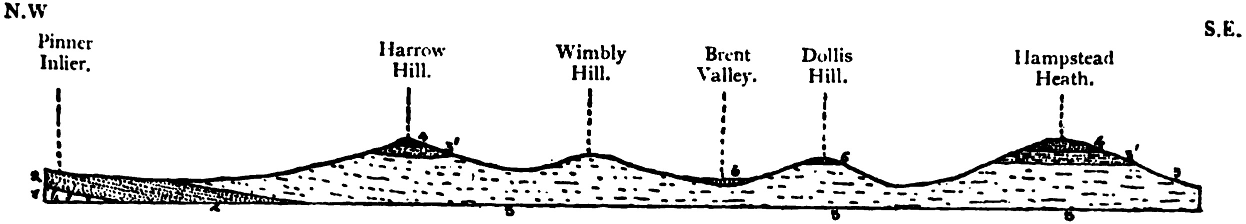


FIG. 1.—Section from Pinner to Hampstead. (SCALE 1 INCH TO 2 MILES.)

By J. LOGAN LOBLEY, F.G.S.

1. Chalk.
2. Woolwich Beds.
3. London Clay.
3'. Upper Sandy London Clay.
4. Bagshot Sands.
5. Hill Gravels (? Glacial).
6. Brent Gravels (Post-Pliocene Alluvium).

EXCURSION TO MERSTHAM, REDHILL, AND REIGATE.

SATURDAY, MAY 21ST, 1887,

(In conjunction with the Croydon Microscopical and Natural History Club.)

Director: W. TOPLEY, F.G.S., Geological Survey.

(*Report by* THE EDITOR.)

Seldom has the Association had to contend with more adverse meteorological conditions than befell the Members who took part in this excursion. Arriving at Merstham at noon, the party heard with regret that their old friend Mr. Gilford, who was to have been one of the Directors, was prevented by the illness of one of his family from being present.

Slightly varying the programme, the Director, who had provided a supply of useful sketch-maps and sections for distribution among the Members present, led the way to the road-side exposure of the Upper Greensand, near the windmill, east of the railway. Here, at his request, Dr. G. J. Hinde, F.G.S., briefly addressed the party on the subject of the nodules which occur in bands in this formation. These nodules were, he said, locally known as "flints," and were, in fact, largely siliceous, containing great numbers of sponge-spicules and cavities, some of which were pseudomorphous after spicules. They also contained globules of redeposited silica, a considerable portion of silica in the Upper Greensand being soluble in caustic potash, and, in fact, in a colloid state. To this the fertility of the Upper Greensand, and especially its suitability for hop-culture, has been attributed.

The Director then called attention to the general features of the district, alluding first to the slight secondary escarpment upon which they were standing, parallel to that of the Chalk behind them, and then to the level pasture-land of the Gault to the southward. Mr. Topley mentioned that the general character of this clay and the luxuriance of its oaks had misled William Smith, who had confused it with the Jurassic "Oak-tree," or Kimmeridge Clay. Beyond the outcrop of the Gault rose the slope of that of the Lower Greensand, the young corn and other plants of arable land on which were liable at a distance to be mistaken for the permanent pasture of the Gault. Nearly the whole of this thick series of sands and fuller's-earth thinned out northward under the London

Basin; while to the south of the Chalk ridge we have none of the Tertiary beds so familiar to us nearer London, though at Caterham, two or three miles to the east of where they then were, the Oldhaven pebble-beds were transgressive on to the Chalk.*

The party then proceeded to the large pits in the Lower Chalk; but threatening clouds made them take refuge in some of the empty lime-kilns, with the exception of a few of the would-be weatherwise, who were caught in a sharp hailstorm in making their way to the church. The Director then called attention to the traces of the so-called Pilgrim's Way, marked by a line of yews to the eastwards,† and following, as it generally does in Kent, the line of the lower part of the Chalk escarpment, so as to be, as has been suggested, well above the level of the tops of the trees in the adjacent primeval forests and swamps on the Upper Greensand and Gault. Avoiding, as it appears to do, nearly all the existing villages, which are presumably of English origin, it is probably a British or prehistoric track, and it is interesting to note that a similar road on the Chalk encircles the Lower Boulonnais.‡

The authorities having had information of the coming of the geologists, the church was carefully locked; but Mr. E. Locke kindly described the building to the party when re-assembled in the churchyard. "It is," he said, "a typical Surrey church, and as such is illustrated in Brandon's 'Parish Churches.' Built with various materials, at various periods, and in as many different styles, it is an object of considerable interest to the geologist, the archæologist, and the ecclesiologist. The nave of the church is Norman, with square abaci and the usual features of the period, but with a curious clerestory formed in the spandrils of the arches and immediately over the columns, and not, as is usually the case, over the apex of the arch. The capitals of the chancel-arch are carved to represent palm-leaves, very conventionally treated, and probably indicating that a knight templar had something to do with its erection. The tower is a plain, but excellent example of 13th-century work, and has a trefoil-headed west door with 'dog-tooth' enrichment. The tower is surmounted by an oak, shingle spire. The greater part of the church is built in Gatton stone, and the roofs are covered with Horsham 'slates,' as are most of the churches hereabouts."

On reaching the village by a pretty footpath from the church, attention was directed to the village smithy, an interesting half-timber 15th-century house, which, after having been allowed to go almost to a ruin, would have been pulled down but for the fact that a few parishioners purchased it and restored the building in the best sense of the term.

---

* *Vide* T. V. Holmes, 'Proc. Geol. Assoc.,' Vol. ix, p. 105.

† Captain E. R. James, 'Notes on the Pilgrim's Way in West Surrey,' 8vo., London, 1871.

‡ W. Topley, "Geology of the Weald" ('Mem. Geol. Surv.'), pp. 382-3.

After a bread-and-cheese luncheon at the "Feathers" the Members hurried southwards towards Redhill, the first halt being at a brickfield north of Battlebridge, where the faulted junction of the Gault and the Folkestone Sands can be seen. Here, however, rain compelled the party to take shelter in a shed, and relieve the tedium of the delay by listening to some humorous verses on a recent excursion read by the author, Miss Forster. In a lucid interval in the gloom-inspiring weather a slight advance was made towards Frenches, where another brickfield should have been visited; but rain, varied by hail, entirely prevented this, though the Members were able in consequence to have an interview with the Jolly Brickmakers.

Some progress being at length made, a sand-pit, nearer to Redhill, was then visited that displayed the Folkestone Beds in rather an interesting manner, showing not only the "false-bedding" common in this series, but also a somewhat faulted and much reconstructed upper portion. The silver sand in this pit was stated by workmen to be "not sharp enough for glass-making."

Train was then taken from Redhill to Reigate, where attention was directed to the extensive cellarage in the escarpment-ridge of the Folkestone Sands, through which the road from the station to the town has been tunnelled. A visit was then paid to the "Castle," in the public gardens, which have recently been newly laid out. Passing under the imitation Gothic archway, entrance to the "Baron's Cave" was obtained from the newly-opened "Sally-port," from which the ascent can now be made with comfort through the extensive excavations, that are kept clean and well lighted, in marked contrast to their condition a few years back. In the "Guard-room," where a large stone ball, said to be used as an echo-producing signal, was exhibited, some incredulity was expressed as to the traditional connection of these excavations with the preliminaries of Magna Charta. The keeper, however, regardless of any difficulties as to cross-country locomotion at a date rather before the introduction of railways, confidently informed the Members that the Barons met here on June 14th, 1215, and proceeded to Runnymede next day.

welcome tea at the "Grapes" Hotel, to which about lown, under the chairmanship of the President, thanks ned to the Director; and, the weather having cleared, a vening stroll of about a mile brought the party to the it Woodhatch, where a most interesting junction between and Atherfield Clays was exposed. In the upper part Weald Clay was a calcareous band apparently composed lissolved *Cyrenæ* and a layer of ironstone; and several were found. Above the swampy junction came the md of the Atherfield, crowded with *Perna Mulletii*, yielded coniferous wood, an undetermined gastropod, fossils probably referable to *Pecten interstriatus* and *ifera.*

valk, across Earlswood Common and past the deeply iron-ection of the Hythe Beds at Redhill Common, brought ionists back to the railway-junction, and terminated a any means unsuccessful in spite of the weather.

REFERENCES.

urvey Map, Sheet 8.

rvey Map, New Series, Sheet 286.

ON.—"Strata below the Chalk." 'Trans. Geol. Soc.,' Ser. 2, pp. 140-143; 1836.

ON.—"Observations on . . . the Lower Greensand." 'Proc. c.,' Vol. iv, p. 201; 1843.

ER.—"Excursion to Redhill." 'Proc. Geol. Assoc.,' Vol. vi, 1880.

—"The Geology of the Weald." 'Mem. Geological Survey,' . 113, 121, 141, 148, 154, 233.

.—"On Beds of Sponge-remains in the Lower and Upper Green-the South of England." 'Phil. Trans.,' Part ii, 1885, p. 403.

ION TO CIRENCESTER AND MINCHINHAMPTON.

AY AND TUESDAY, MAY 30TH AND 31ST, 1887.

Professor ALLEN HARKER, F.L.S., F.G.S., Professor tural History, Royal Agricultural College, and EDWIN HELL, F.G.S.

(*Report by* PROFESSOR HARKER.)

mal Excursion was made on May 29th to Birdlip, to give Members as could join a general idea of the lie of the s. It is not until the stranger reaches the actual escarp-ne realizes that he has gradually been ascending from the irencester through a vertical height of nearly 600 feet.

From a projecting spur of the escarpment in the grounds of the "George" a magnificent view of the valley of the Severn is obtained—the hills of the Forest of Dean, May Hill, and the Malverns forming the background from left to right; Gloucester Cathedral, the Abbey at Tewkesbury, Cheltenham, and to the north Bredon Hill, being conspicuous landmarks in the vale; nearer still the outliers of Churchdown and Robin's Wood Hill, the latter still capped by Inferior Oolite, evidence the mode in which the vale has been partially excavated. Close to and below the grounds of the hotel the Birdlip Section of the Inferior Oolite was examined; and then the party walked to Crickley Hill, where a well-exposed section reveals some feet of the characteristic Pea Grit or Pisolite. The weathered, lozenge-shaped granules mainly composing this rock were strewn in vast numbers over the slopes of the hill beneath the beds, and from their fairly uniform size present a striking appearance. Several of the characteristic Brachiopods were obtained, and most of the party eagerly secured specimens of the Pisolite. A return to Birdlip was made across the northern side of the hill, whence a still better view is obtained of Cheltenham and the escarpment, extending to the opening of the Vale of Evesham. On the drive back to Cirencester the successive beds of Great Oolite and Forest Marble passed over were pointed out.

May the 30th.—After a visit to the Corinium Museum, the Members assembled at the Royal Agricultural College, and devoted some time to the inspection of its Museum, of which Lycett, in his 'Geology of the Cotteswolds,' speaks very highly. In addition to the College geological collection, Professor Harker had arranged in his laboratory a small collection of fossils obtained by himself and students from the quarries in the neighbourhood, illustrating the Great Oolite, Bradford Clay, Forest Marble, Cornbrash, Kellaways Rock, and Oxford Clay, most being from quarries which were in the programme for the day. A visit to a huge concretionary block of Kellaways Sandstone, which has been mounted on a pedestal in the midst of a grove of trees in the Botanic Gardens, concluded the inspection of the College. Professor Allen Harker, who acted as *cicerone* for the day, described the block (which weighs over 25 cwts.) as specially interesting, as having come from a section which was the *pièce de résistance* of the day's excursion. The party then walked to Jarvis's quarry, two miles on the Ackman Street, or Bath road, where there is a section showing the uppermost beds of the Great Oolite, capped by a few feet of fissile

Forest Marble. A number of fossils were obtained, including *Terebratula maxillata*, *Pecten vagans*, teeth of *Lepidotus* and *Strophodus*, and *Lima cardiiformis* in abundance. This concluded the morning's programme, and a return was made to Cirencester for lunch.

At 2 p.m. the party drove to South Cerney, a distance of four miles. On the way, in crossing the Thames and Severn Canal, the classic spot was pointed out where William Smith found the Kellaway's Rock. The carriages were left near the village, and a careful examination of the section on the Swindon, Marlborough, and Andover Railway, through the Kellaway's Rock, was made. This very remarkable section has been described by Professor Harker (with a photograph of it at the most picturesque period of its excavation) in the 'Proceedings of the Cotteswold Club.'* Some hour and a half or more were spent in examining the curious concretionary masses *in situ*, and in excavation, with their fossils (notably their large masses of imbedded wood); and, after a brief description of their history, a discussion was held on some of the remarkable features presented. Among the chief fossils in the Kellaway's Rock were *Ammonites Calloviensis* *Myacites recurva*, and *Waldheimia obovata*.

A walk back towards Cirencester along the railway brought the party to the village of Siddington, where there is a large quarry in the Forest Marble worked for the sake of its shelly limestone, which is used for a road material, and for its tile-stones, largely employed in the neighbourhood for roofing-purposes. Here, again, fossils are fairly plentiful, the chief species being *Ostrea Sowerbyi*, *Pecten annulatus*, and *Lima cardiiformis*; but they are not so numerous as in a railway-cutting not far off, where a small section shows the Cornbrash and its junction with the Forest Marble. The Cornbrash is about 7-8 ft. in thickness, and quite full of fossils. *Homomya* and *Pholadomya* are genera very abundantly represented, as well as Brachiopods and Ammonites. Among the chief species are *Terebratula lagenalis*, *T. intermedia*, *Waldheimia obovata*, *Ostrea flabelloides*, and *Ammonites macrocephalus*. A short account was given by the Director of the extent and character of the Forest Marble as shown by this cutting and the quarry just left, these two sections, with a few smaller ones in the neighbourhood, exposing the whole of the Forest Marble at its average thickness.

---

* Vol. viii, p. 176 (1885).

On the way back to Cirencester two collections of the local ornamental stone, known as the "Dagham stone," were visited, one very large accumulation being kindly shown in the private garden of its owner, Mr. Gillett, who invited the party to pass his way. The stone is a hard oolitic limestone, perforated by irregular holes in such a manner as to present a reticulate appearance.* It is used in buildings and rockeries.

Tuesday, May 31st, 1887. (*Report by Mr. E. Witchell, jun.*).—The party proceeded from Cirencester to Stroud, where they were met by Mr. E. Witchell, F.G.S., Mr. W. H. Hudleston, F.R.S., the Rev. H. H. Winwood, F.G.S., and several other members of the Cotteswold Field Club. The direction of the party for the day was under Mr. Witchell.

A move was soon made for Dudbridge, some of the party riding, while others preferred a walk by the side of the canal. The brick-pit at Dudbridge was visited, and the Middle Lias beds were explained by Mr. Witchell, who compared them with those at Stroud, which are more ferruginous and consolidated. The "*spinatus*"- and "*margaritatus*"-beds were found in close contact, and it was remarked that Dr. Wright had observed the same occurrence at Dursley. A few fossils were obtained, of which *Avicula inæquivalvis*, *Unicardium*, and *Pleuromya* were most abundant. At the upper brick-field there was an excellent section of the *spinatus*-bed, with the overlying Upper Lias; and here, in the concretionary rocks, were found many characteristic fossils.

The party then proceeded to Rodborough Hill, passing over the Upper Lias and Cotteswold sands, and making the next halt at the parish pond, behind which there is a small exposure where the Pea-Grit was shown, at this point overlying 40ft. of Lower Limestone. At the request of the President, Mr. Witchell pointed out the successive formations they had now passed. He traced the bed before them, from Birdlip, where it was eight feet thick, to where it vanished at a point five miles away in an opposite direction. The presence of a small oyster on the upper surface of the Lower Limestone beds proved that a pause of some duration had occurred in the deposition of the strata, enabling the oyster-bed to form. Hammers were soon at work in the Pea-Grit beds, and the characteristic shells *Terebratula plicata* and *Rhynchonella sub-*

---

* These holes may be due in part to the decay of organic remains, such as branching corals or sponges. *Vide* S. P. Woodward, 'Geol. Mag.,' 1867, p. 405.

angulata were obtained. The next section visited was the old quarry below the Fort, which has now been sloped down and all the beds covered up, but two small exposures remain, showing the Oolite Marl with its characteristic *Terebratula fimbria*, and with the *Nerinæa*-bed beneath. But from the hard nature of the rock. fossils can only be obtained at the expense of time and labour, and few or no prizes were taken from this quarry. *Terebratula submaxillata* and *Rhynchonella sub-tetrahedra* do, however, occur, A move was then made for the upper quarry, near the Fort, where the Upper Freestone Beds and Ragstone Series above form a fine section. Thecharacteristic gryphite (*Gryphæa sublobata*) was found, and good specimens of other fossils—*Terebratulæ* and *Trigoniæ*—were taken. *Terebratula globata* was especially abundant in the upper beds, or *Clypeus* Grit and White Freestone. A short explanation was here given, and on leaving the quarry the party formed a circle upon the escarpment of the common, where Mr. Witchell gave a short discourse upon the physiography of the district. It was remarked that the presence of the same beds lying in one plane in adjoining hills prove the rocks of the neighbourhood to have been originally connected, and the valleys between them to have been formed by the slow but sure process of denudation.

At the Bear Inn the company partook of a light lunch, after enjoying a fine view of the Woodchester valley, and obtaining a few specimens from the roadside quarry. The Great Oolite quarries on Minchinhampton common were afterwards visited, and some fossils were found, the fine character of the stone being much admired by all present. Among the most characteristic species are *Purpuroidea Morrisii*, *Nerinæa Voltzii*, and *Tancredia brevis*. The party then crossed the common to Walls quarry, another rich field for geologists, and here several ladies and gentlemen inspected the large cave under the guidance of a native whose geological studies had been strictly professional, and who used a pickaxe in place of the amateurs' hammer. Soon after four o'clock the signal was given for the return to Stroud. The Members dined at the Imperial Hotel, and Mr. Witchell received a cordial vote of thanks for having conducted them on one of the pleasantest field days they had ever enjoyed.

Those who took part in this excursion and remember the geniality of Mr. Witchell, and his readiness to impart his wealth of

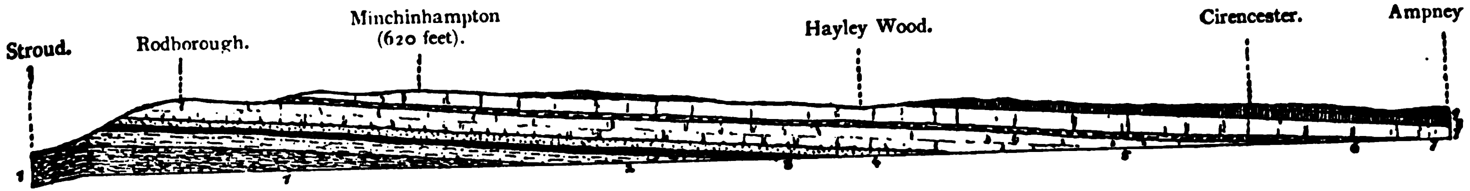


Fig. 1.—Diagram-Section from Stroud to Cirencester. (Length, about 15 Miles.)

By H. B. Woodward, F.G.S.

1. Lower Lias.
2. Middle Lias.
3. Upper Lias Clay.
4. Cotteswold Sands.
5. Inferior Oolite.
6. Fuller's Earth.
7. Great Oolite.
8. Forest Marble.
9. Cornbrash.

local knowledge to any Member who appealed to him, will have heard with profound regret of his sudden death in a quarry a few weeks after the Whitsuntide excursion.

REFERENCES.

Geological Survey Map, Sheet 34; and Explanation (Geology of parts of Wiltshire and Gloucestershire), by A. C. Ramsay, W. T. Aveline, and E. Hull; 1858.

Buckman, Prof. J.—"On the Oolite Rocks of Gloucestershire and North Wilts." 'Quart. Journ. Geol. Soc.,' Vol. xiv, p. 98; 1858.

Harker, Prof. Allen.—"On a Remarkable Exposure of the Kellaway's Rock in a Recent Cutting near Cirencester." 'Proc. Cotteswold Nat. Club;' 1885.

Lycett, Dr. J.—'The Cotteswold Hills. Hand-book introductory to their Geology and Palæontology;' 1857.

Witchell, E.—'The Geology of Stroud;' 1882.

EXCURSION TO RICKMANSWORTH.

Saturday, June 4th, 1887.

(In conjunction with the Hertfordshire Natural History Society.)

Director: John Hopkinson, F.L.S., F.G.S.

(*Report by* The Director.)

Sections exposed in making the new line of railway from Pinner to Rickmansworth were examined by the Association in June, 1886.* The London Clay and Woolwich and Reading beds were then seen, and the line was left near Moor Park before it crosses the valley of the Colne. On the opposite side of this valley the Chalk has been cut into, and this Excursion was originally arranged to enable the Members to examine sections of the Upper Chalk thus exposed. It was found, however, towards the end of May, that the cuttings in the Chalk were no sooner completed than they were covered up with a layer of soil on which grass was destined soon to grow, and the programme had to be altered. Although the route now chosen was not, perhaps, so interesting geologically as that which had to be abandoned might have been, it had the advantage of being more picturesque.

From Rickmansworth (London and North Western) Station † the members of the two societies crossed the fields to Woodcock Hill Kiln, halting on the way on the summit of a hill, from which was obtained a view of the valley of the Colne, and of the junction with it of the subsidiary valleys of the Chess and Gade.

---

* See 'Proc. Geol. Assoc.,' Vol. ix, pp. 548-550.

† The Metropolitan Station has now been opened.—*Sept.*, 1887.

This hill, the Director stated, owed its existence to the bed of pebble-gravel seen upon it. The top, as usual with hills of chalk (as well as of clay) capped with gravel, was flat, and there was a steep slope towards the valley of the Colne and a gentler slope in other directions. This conformation was due to the preservation from sub-aërial denudation of the gravel-covered portion of the hill. The rain falling upon it percolates through the gravel without washing it away, whereas outside the margin of the gravel the rain washes away the chalk, or, by the carbonic-acid it contains, chemically dissolves it, and this more rapidly towards the valley than towards the higher ground behind the hill; the steep slope being formed by the resistance to denudation of the edge of the bed of gravel, which, however, would gradually give way by the undermining of the chalk. Towards the west another similar gravel-capped hill was seen, the steep edge, showing the extent of the gravel, being distinctly apparent. The gravel was stated to be of doubtful age, but certainly as old as Middle Glacial, similar gravels, of which the beds covering these two hills seemed to be portions, elsewhere running under boulder-clay.

A few minutes' further walk brought the party to Woodcock Hill Kiln, where sections of the Woolwich and Reading Beds, and of the basement-bed of the London Clay, were seen. As these sections appeared to be in the same state as when visited by the Association in 1882, and as an account of them, with a section of the beds in the higher pit, appeared in the 'Proceedings' (Vol. vii, p. 398) in the report of that visit, they need not here receive any further mention.

After a pleasant stroll across the fields, by woods in which the bluebell was flowering in profusion, giving them a rich carpet of blue, the high-road from Rickmansworth to Pinner was reached. This road borders Moor Park from Rickmansworth to Batchworth Heath, a distance of a mile and a half, one-third of which was now traversed to arrive at the Heath.

At Batchworth Heath, the name formerly of the common, now of the hamlet of cottages surrounding the common-land, we have again a gravel-capped hill, 360 feet above sea-level; but here the gravel, a pebble-gravel like the one before visited, is on the London Clay. This point commands extensive views of the country to the south and east. Below, on the south, lies Ruislip Reservoir, and far beyond are seen the hills of Surrey; on the east are Pinner Hill and Oxhey Woods, and between, beyond Pinner on its inlier of Woolwich and Reading Beds, stands out Harrow Hill on the London Clay capped by an outlier of the Bagshot Sands. These sands have preserved, and still are preserving, the summit of the hill from denudation, achieving, but on a larger scale, that which the bed of gravel first visited has done for its little hill.

After pointing out the chief features of the landscape, geological and otherwise, the Director made a few general remarks on the geology of Hertfordshire, stating that the county might be divided into three sections, the middle and main portion being on the Upper Chalk almost entirely covered by superficial deposits of glacial gravel, valley-gravel, boulder-clay, and clay with flints, and chiefly under arable culture; the northern portion consisting of Downs of bare, or nearly bare, Middle and Lower Chalk, devoted to sheep-walks and turnip-farming; and the southern, of the London Clay, with a narrow fringe of the Woolwich and Reading Beds, forming a rich cattle-grazing and dairy-farming district. The country here seen was, he said, of this character; but, though viewing it from Hertfordshire soil, it was the gently-undulating and richly-wooded north-western corner of Middlesex which formed the prospect.

Entering Moor Park, and still traversing the bed of pebble-gravel, Cardinal Wolsey's oak was pointed out on the left—a tree not planted by him, but under which, it is believed, was his favourite seat; and all around were seen the oaks pollarded by order of the Duchess of Monmouth on her husband's execution in 1685, most probably from the desire to prevent them from ever being used as timber for the Royal Navy.*

The "Upper," or "Old Pleasure Grounds," were then visited, by the kind permission of Lord Ebury. These grounds are about twenty-five acres in extent, and they command a fine view of the country to the north, beyond the valley of the Colne. The boundary of the Batchworth Heath gravel-bed passes across them, and the London Clay on which it rests holds up the water which percolates through the gravel, a circumstance which has been taken advantage of in forming an ornamental sheet of water in the grounds, which adds much to their picturesqueness.

---

* See Canon Gee's remarks on this subject in his paper on "Famous Trees in Hertfordshire," 'Trans. Watford N. H. Soc.,' Vol. ii, p. 14.

Almost too long did the party linger in these beautiful grounds, which were left with reluctance only just in time to catch the train from Rickmansworth to Watford by hurrying across the Park. The train was left at High Street Station in order to visit Watford House, the residence of Dr. A. T. Brett, who entertained the party with welcome refreshments on the lawn. The assembled company, to the number of 34—not all who had taken part in the Excursion, for some had to go on direct to London—were then photographed, and the proceedings of the afternoon were brought to a close by the passing of a vote of thanks to Dr. Brett and to the Director, on the proposition of the President of the Association, seconded by Mr. W. B. Gibbs.

REFERENCES.

Ordnance Survey Map, New Series, Sheet 255.

Geological Survey Map, Sheet 7 (Drift edition).

1864. WHITAKER, W.—'Memoir on Sheet 7—Geol. of Parts of Middlesex, Herts,' &c. See Index, 'Batchworth Heath' and 'Woodcock Hill.'

1872. WHITAKER, W.—'Mem. Geol. Surv.,' Vol. iv, "Geol. of London Basin," pp. 219, 301, 583-6.

1883. HOPKINSON, J., and WHITAKER, W.—'Proc. Geol. Assoc.,' Vol. vii, p. 397; and 'Trans. Herts. Nat. Hist. Soc.,' Vol. ii, p. xxvii.

1887. HOPKINSON, J.—Introduction to Pryor's 'Flora of Hertfordshire,' pp. xiv-xvii.

EXCURSION TO AYLESBURY.

SATURDAY, JUNE 11TH, 1887.

Director: W. H. HUDLESTON, Esq.

(*Report by* THE DIRECTOR.)

The party was joined by several Members of the Vale of Aylesbury Naturalists' Club. Upon the arrival of the company by the one o'clock train a move was at once made towards Mr. Hill's brick-fields in the Bierton Road. Here the Director requested the members of the party to examine for themselves the remarkable junction between the Upper Kimeridge Clay and the Portland Conglomerate (Lydite bed). After this inspection had been made he briefly addressed them on the general object of the Excursion.

Aylesbury is the nearest point to London where the Jurassic rocks are exposed to view, and this must be his apology for having brought them to a place which at first sight did not offer any very visible results by way of section. The town itself was built on a boss of Portlandian rocks, of which the middle member, as he would afterwards show them, was of the most importance in that immediate district. The position of the town was one of considerable strength as a Portlandian outlier. The church stood on a platform 305 feet above the Ordnance Datum, and nearly 60 feet higher than the low-lying meadows of the Thame valley. Such a position was a natural stronghold, and, in fact, the place was held by the British against the Saxons till quite late in the sixth century. There were numerous other Portlandian outliers in this part of Bucks.

He would now direct their attention to the section in the brickyard. There were plenty of fossils in the Upper Kimeridge Clay there, but they required care both in search and in the preservation of them. The fossils were similar to those in Locke's pit at Hartwell, which was on the same horizon. The uppermost three or four feet of this clay presented considerable differences in appearance, but the Director pointed out that this was merely due to surface action. When he was last at Aylesbury, seven years ago, the drainage works, which were then being carried through the Market-place, proved most clearly that all the underlying clay continued fresh in colour and fossiliferous up to the very junction with the Portlandian Conglomerate. Some gentlemen objected to the use of the term conglomerate for a number of loose black pebbles of small size in a half-dissolved brash, but here was the great interest in the section presented by Mr. Hill's brickyard, viz., that the party there saw, not only an excellent junction between the Kimeridge or Hartwell Clay and the lowermost Portland rocks, but they also saw those very beds in a totally different physical condition to that in which they existed when protected from atmospheric solvents. They might take his word for the fact that these soft, crumbly beds, with their phantom fossils and small, black pebbles, constituted under the Market-place a series of beds about five feet thick, of intense hardness, with a number of large Portlandian fossils, well-preserved. Above this there came a variable series of sands and brownish-coloured beds, and upon these rested the great middle series of rubbly limestones, which formed the floor of so much of the town of Aylesbury. This also had a peculiar set of large Portlandian fossils, many being identical with those in the conglomerates below. He had fortunately just picked up in the street a most characteristic fossil—*Myoconcha Portlandica*—which he exhibited as a specimen from those beds.

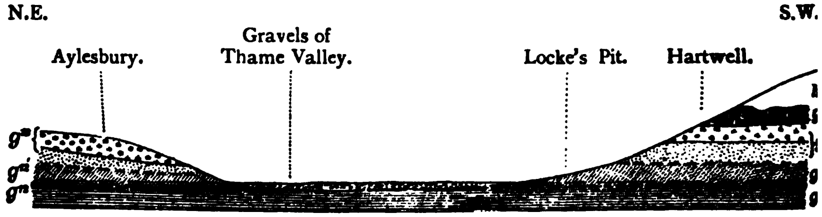


FIG. 1.—Diagrammatic Section, 2¼ miles, by the Director.

h Lower Cretaceous.
g^{14} Purbecks.
g^{13} Portland Stone and Sand, with Conglomerate Bed at base.
*g*12′ Sandy Glauconitic Clays with *Ostrea expansa*, &c., very fossiliferous (Middle Portlandian of the French).
*g*12 Dark waxy Clay, passing downwards into ordinary Kimeridge Clay.

After a short stay for practical work with the hammer the party moved on through the town, viewing some specimens exhibited by Mr. S. G. Payne, calling at the George for light luncheon, and visiting the Parish Church, and thence proceeded along the Hartwell Road until Mr. Locke's brickfields were reached. The Director observed that this was not the best time of the year for procuring fossils from this pit, which had been celebrated during so many years for yielding what were called Kimeridge Clay fossils. But he insisted that if we are still to call this Kimeridge Clay we must make a very strong distinction between Upper and Lower Kimeridge, as their respective faunas had scarcely anything in common. He then alluded to the views of [illegible] Sœmann, which had been incorporated in the work of De Loriol and Pellat, to the effect that the Hartwell Clay contains the same fossils as the so-called Middle Portlandian Clays of Boulogne. Whatever name we give to the beds on either side of the Channel their practical identity could scarcely be doubted. The Director then pointed out in what respects these fossils differ from those, for instance, of the Lower Kimeridge of Ringstead Bay and other localities, and the Members afterwards succeeded in collecting such characteristic fossils as *Ammonites biplex*, *Thracia tenera*, *Astarte Sæmanni*, *Arca texta*, &c., &c. Before leaving this pit attention was directed to a freshly-cut section at the west end, just beneath the fence, where the Portlandian Conglomerate, in a state of good preservation, might be seen resting directly on the Hartwell Clay. Here the members of the party were able to realize the difference between this tough blue rock, full of palæozoic cherts or lydites, and the same in a state of decay, as seen in the previously-visited brick-field at Aylesbury. The thickness of this series is about 5½ feet at this place, including, with the hard stone, some softish greensands full of *Serpulites*. The largest pebbles and the hardest rock are at the very bottom, where a spring of water is thrown out by the clay. Small pebbles and glauconitic granules pervade the entire mass of rock visible in the section. Fossils are very numerous.

The party then moved on to the Bugle pit, and here the Director pointed out that the present face of rock is about 20 feet further back than when the Association last visited this famous quarry. As the vertical exposure is not very extensive a pit of considerable depth had been sunk below the lowest worked stone in order to extend the range of the section. This disclosed the yellow sands, about five feet thick, below the worked stone, and some three or four feet of a tough bluish limestone with very few fossils, known as the double rock. An accumulation of water prevented further sinking without pumping apparatus. The Director said he would avail himself of the present opportunity to give a summary of the general development of the Portlandian rocks in this part of Bucks, and, jumping into the hole, he drew a rude profile on the sand with the point of a trowel by way of illustration. The base of the "pendle" might be taken as the bottom of the Purbecks. Immediately below this the Portlandian rocks may be said to commence, and in this quarry what he would call the *Upper Portlandian Limestone* had a thickness, including the two building-stone tiers, of over 10 feet. The subdivisions he would detail presently, merely remarking that the limestone was characterized throughout by *Ammonites boloniensis*, and by a considerable number of *Gastropoda*, in addition to a large series of *Conchifera*. This he would call No. 1. The next series, No. 2, was the buff-coloured sands which they saw beneath them, terminating downwards in a wet, dark, clayey sand. Of the great series of middle limestones, which he would call No. 3, they only saw an upper and less fossiliferous phase in the hard blue limestone at the bottom of the hole, but the Director had every reason to believe, from what he had seen in a drain below the Bugle public-house, that the real Aylesbury Limestone, or "rubbly beds" of Mr. Blake, with *Unicardium circulare*, *Myoconcha Portlandica*, &c., did exist at Hartwell. Below these came No. 4, a series which they all had to take very much upon trust for the present, but which undoubtedly represented a second sandy set of beds, and beneath this came No. 5, a variable mass of rock, with which the party were already well acquainted, and which they might call the Portlandian Conglomerate or anything else they pleased. It follows, therefore, that there are three distinct rock masses, mainly calcareous, separated by a lower and an upper sand. Such may be deemed the development of the Portlandian rocks in that part of Bucks, and although certain comparisons might be made with other areas, at any rate as far as Bourton and Swindon, where the basal pebble-bed still acted as a guide, the Director was not prepared to carry such comparisons any further south. (2) He would now say a few words relative to the Upper Portlandian Limestone of the quarry itself. The very highest bed—a softish brash just under the "pendle"—contained a few cyprids (probably *Cypris Purbeckensis*), but it also contained abundance of large oysters, and towards its base there is a line of Ammonites. Then comes the upper hard rock, quarried for stone, and then a lower brash. All these beds he would throw into one section, as the uppermost sub-division of the Upper Portlandian Limestone, about three feet thick, characterized in some places by *Cerithium Portlandicum*, and very rarely by *Neritoma sinuosa*. The lower division, some six feet thick, consisted of the "creamy limestones" of Mr. Blake, mostly extracted for lime-burning. These were very fossiliferous, especially on a line not many inches from the top, where an extremely pretty little *Natica* and many other interesting gastropods occur in considerable abundance. The lower portion of this series, including the second building-stone, is of less interest. If the party turned their attention for a moment to the Purbeck beds they would at once perceive that there was no visible discordance between the Portlands and the Purbecks. The latter was well represented by the "pendle," a pale fissile limestone by no means devoid of cyprids, as well as fish and insect remains. Bones of very large saurians might be seen at the present time, but they were in a crumbly and imperfect condition. The Purbecks are but thinly developed, and none but Lower Purbecks are known to occur. And yet there seems to have been a considerable amount of erosion amongst the Purbecks themselves, if appearances in this quarry can be trusted, though not to the same extent as is known to have occurred at Swindon.

At the Round Hill the Director observed that they were now fairly out of the Jurassics, yet he could not tell them for certain the age of these white sands. M. Sœmann had drawn a section in which he represented an ascending sequence, above the Purbecks of Hastings Sand, Weald Clay, and Lower Greensand. These beds might possibly be of Wealden age, and the discovery of *Endogenites erosa* in the neighbourhood, long ago, rather points in that direction. The beds were evidently associated with carbonaceous matter, the decay of which had engendered powerful solvents, which had acted both in dissolving out the basic matter of the sands, and, probably, also in effecting the solution of some of the silica which had run together in the form of these curious strangulated concretions, sometimes known as the "Doctor's bowels."

Directing the attention of the party from the quarry itself to the Chiltern Hills, he observed that whilst they had that magnificent view before them, as they saw the Jurassic rocks disappear beneath the Chalk escarpment, it was impossible to avoid wondering how these same rocks fared when thus removed from sight. When last the Association visited Stone it was then believed that not a single member of the entire Jurassic system survived as far as London, some forty miles off. But now, owing to the investigations of Professor Judd, President of the Geological Society, it had been shown clearly that a few feet of the Great Oolite alone survived as a thin wedge between Cretaceous beds and the Palæozoic rocks.

As it was now getting late in the afternoon the party commenced the walk home, returning by way of the Egyptian Springs and the lake in the park. Aylesbury was reached at six, and full justice was done to an excellent dinner provided at the George, the Rev. C. L. Jeayes, President of the local Club, being entertained as the guest of the Association. The services of the Director were duly acknowledged in a vote of thanks, proposed by the President, and seconded by the Secretary (Dr. Foulerton), after which the party took the 7.20 p.m. train for London, having spent a very pleasant day.

WORKS OF REFERENCE.

Sheet 46 of Geological Survey Map.

Fitton, W. H.—"Strata below the Chalk," 'Trans. Geol. Soc.,' 2nd series, Vol. iv.

Morris, J.—"Excursion to Aylesbury" (1873), 'Proc. Geol. Assoc.,' Vol. iii, p 210.

De Loriol, P. E., and Pellat, E.—'Etage Portlandian des environs de Boulogne,' p. 189.

Blake, J. F.—"Portland Rocks of England," 'Q. J. G. S.,' Vol. vi, p. 189.

Hudleston, W. H.—"Excursion to Aylesbury" (1880), 'Proc. Geol. Assoc.,' Vol. vi, No. 7.

EXCURSION TO THE MOUNT, EALING, AND HORSINGTON HILL.

June 18th, 1887.

(In conjunction with the Ealing Microscopical and Natural History Society.)

Director: J. Allen Brown, F.G.S., F.R.G.S., &c.

(*Report by* The Director.)

The principal object of this excursion, which was attended by about a hundred Members, was the examination of exposures of stratified beds believed to be contorted and furrowed by the action of ice, at the Mount, Ealing, where a second large reservoir is now being constructed for the Grand Junction Water Company.

The party was met at Ealing Station by the Director, and proceeded by way of Castlebar Hill to examine a section of very high-terrace river-drift, exposed on its lower slope at about 125 feet above Ordnance Datum. The sections at this pit present features of some interest, considering the high level of the deposits. The upper terrace river-deposits are here over 20 feet thick, and much thicker than in many parts lower down in the valley.

It is remarkable that the upper surface of the gravel beneath the brick-earth dips towards the higher part of the hill to the north, and that the oldest gravel, which is nearly horizontal, has been eroded in the opposite direction to the general dip of the valley-deposits, thus forming a channel filled with gravel and sand, and showing that after the deposition of the thick, nearly horizontal, stratified gravel beds beneath, the water receded, and that apparently this spot formed a temporary land surface, traversed by a tributary to the main stream. The same evidence of a stream having cut a channel in the old gravel has been found in pits more than 200 yards to the south.

This section illustrates in a marked manner the erosion of the Thames Valley, and the deposition at successive periods of the gravel and brick-earths; and shows that by the retreat of the waters at intervals from different spots, habitable land surfaces were formed, traversed by minor streams ; the subsequent return of the waters of the main stream again submerging such old land surfaces and depositing river-drift matter upon them.

Two very fine flint implements have been found from five to eight feet below the present surface, besides worked flakes. The implements are of the oldest type, *i.e.*, of the St. Acheul form and abraded. One of them, which is nearly six inches long, is deeply ochreous in colour, and contains old cracks produced by frost, the fissures being filled with black carbonaceous matter ; the other has a glossy black surface; both of them being in the Director's collection.

The Director pointed out that gravel is found in pockets in places all the way up Castlebar Hill, while near the top at the 155-foot contour there is a bed of subangular river-drift gravel, surmounting a deposit of rounded pebbles of apparently greater age, but at too low a horizon to belong to the Bagshots.

The Members then walked along the ridge to "the Mount." The present excavation is a short distance north of the one made in 1883, and is on the north slope of the hill. The latter is at the top, and was examined by the Members of the Association, and afterwards described in a paper read at the Meeting of the Association in June, 1883.*

In the sections inspected at the Excursion in 1883 the exposures showed finely stratified beds of fine sand and loam, traversed and disturbed by deep furrows and channels filled with red sand, rounded pebbles intermixed with smaller ones of quartz and other rocks, and large fragments of sarsen.

These beds were nearly horizontally stratified, with a slight dip to the south, except where the furrows occurred, but they were pressed together and twisted under the channels, some of which were over 50 feet long. The evidence was very strongly in favour of the flexures and contortion of the beds (clearly caused by pressure from above) being due to the stranding of masses of ice, which, afterwards melting, deposited the drift found in the pockets.

---

* *Vide* 'Proc. Geol. Assoc.,' Vol. viii, p. 172-181.

Another theory often applicable to irregular beds of gravel, *i.e.* that such pockets might be due to the disturbance of the beds by underground springs, was then, as in the present exposures, quite untenable; since on such a hypothesis the curvature of the beds should be most marked nearest the place where the underlying substance was removed, and should extend upwards towards the top of the overlying beds—whereas the opposite is the case here, the bedding becoming horizontal again a short distance beneath the contorted or compressed lines of stratification, and strong impermeable loamy clay occuring beneath them.

At and around the site of the present reservoir numerous boulders of small size have been, and still may be found, some of which are striated. In the Director's collection from the fields there may be found boulders of granite (three varieties), quartz, quartzite, veined greenstone, trap, Carboniferous Limestone, red sandstone, Upper Oolite, Forest Marble, Lower Greensand with glauconite, Bargate Stone, Chalk Rock, tabular and nodular flint, Sarsen and others not determined, intermixed with rolled flint pebbles.

The evidence derived from the sections in the first excavation in 1883, of glacial agency, or the action of large masses of ice as far south as Ealing, is confirmed in the present exposures, and the further development to the north of the stratified beds opens up an interesting question as to the age of that deposit. First, it is well to point out some new features in the present sections which seem to place beyond doubt the nature of the agency by which these laminated beds underlying large masses of gravel, sand, large sarsens, and other rocks were deposited on the top and higher slopes of this hill, which seems to have been, even when the stratified beds were formed, an undulating or rising bottom beneath the waters.

The contorted channels or pockets of ice-drift now only extend about 400 or 500 feet down the hill from the road—lower down the laminated beds become parallel and regular—and the furrows filled with detritus are absent. At a still lower level, rather beyond the northern limit of the excavation, there is yellow loamy clay. It is very probable that all this ground and much of the country to the north was once covered by similar ice-drift, which has since been denuded and removed by fluviatile and sub-aërial action.

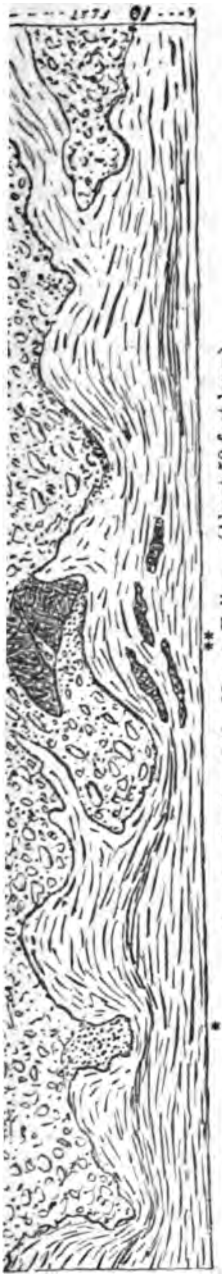


FIG. 1.—Section at the Mount, Ealing. (About 50 feet long.)
* Included mass of sand. ** Included deposits of purple clay.

The contortion and disturbance of the stratified beds beneath and around the irregular deposits of hard concrete-like gravel, &c., has been markedly shown all over the upper part of this excavation. In some of the sections the laminated beds are curved up, wave-like, on one side of the channels filled with compressed gravel, apparently showing the point of greatest resistance encountered by the grounding mass of ice which afterwards deposited it. In others, long tongue-like masses of sand and gravel, with inclosed deposits of purple clay, are seen extending like irregular furrows into the midst of the stratified beds, bending and compressing the lines of stratification, and often apparently churning them up until the bedding is lost.

It is noticeable that above these irregular conglomerated masses of shingle, sand, and purple clay, the stratification is also destroyed, and the loam and sand which alternately compose the laminated beds are mixed up, as if on the melting of the mass of ice the sides of the upper part of the furrow had fallen in.

The Director said he had measured and sketched a large mass of combined stratified beds, with the gravel, &c., above it, which was temporarily left standing in the excavation. The gravel was continuous as an irregular deposit, and may have been on an average four feet deep and nearly 50 feet long, with a width of 18 feet. This patch was much larger, but it had been cut off and isolated by the workmen. Such a quantity of matter, without the underlying beds, must have weighed nearly 150 tons, and if, as appears to have been the case, it was all thrown down together, including a boulder of sarsen, the mass of ice which deposited it must have been of the proportions of a small berg.

The pressure exercised by masses of stranded ice, pushing before them, contorting and churning up the laminated beds into the remarkable flexures now exposed, seems to be the only means which could have brought about such results. The ice itself, perhaps interstratified with gravel, sand, and clay, came probably from the westward or north-westward. It may very well have been derived, in greater part at any rate, from the ice-mantle and glaciers, which are believed to have extended in the middle part of the Post-Pliocene period into the Midland Counties, and even into Essex.

Some such a condition of the country must have occurred about this time in this part of Middlesex; and we have not far to seek even for the direct action of a glacier or an ice-foot, as at Finchley, about six or seven miles away, there is the well-known large deposit of boulder clay, with its contained striated boulders of Northern rocks, of which we have probably the representatives on the Mount, above the ice-borne gravel to which reference has been made.

The Finchley deposits, as well as the scattered detritus just mentioned, appear to indicate either the occurrence in the heart of Middlesex of the moraine of a glacier, or they are the ice-borne detritus and mud deposited under subaqueous conditions.* Coming now to the laminated beds of loam and fine sand overlying the brown sandy clay, which is found from the trial borings to occur beneath them, the stratification or dip of these deposits has been clearly shown to follow the slope of the hill, and it has been proved by the borings, as well as shown by the sections, that the beds lie unconformably upon the London Clay. They are, however, thicker at the top of the hill, where they are probably 35 to 40 feet in thickness, and thin out as the lower part of the excavation is reached, a short distance below which they disappear, and denuded London Clay comes to the surface.

---

* *Vide supra*, p. 144-147.

The result of the trial-borings is as follows:—At the upper part of the excavation, which is within 18 or 20 feet of the top of the hill, the Lower Eocene is not reached at 29 feet 6 inches. About the centre of the works, or at 156 feet elevation, the London Clay is reached at the depth of 34 feet from the surface, while at the extreme northern end, the London Clay was met with at 22 feet 6 inches from the surface, which is there at the 136 foot contour.

These beds extend as an irregular terrace, overlooking the Thames Valley to the south, as well as the wider basin on the north, over the top and higher slopes of Hanger Hill, and they have been traced by the Director beyond, to the higher ground overlooking Twyford Abbey down to the 120 foot contour. In fact they occur all along the upper slopes of the higher part of the ridge dividing the Thames Valley from the wider extension of the basin on the north, from Castlebar Hill to the eastern extremity of the ridge, where it descends to the lower ground of East Acton.

The dip in the stratified beds and their unconformability to the London Clay was not so evident in the sections exposed in 1883, when the first excavation was made, and the occurrence of thin plates of mica and light clay bands and sand in the deposit gave rise to the hypothesis in the minds of some of the geologists then present, that this formation might belong to the Bagshot series, a remnant of which is found on Harrow Hill. The sections now seen will, no doubt, entirely set aside this suggestion, in view of the unconformability of the beds to the London Clay, let alone the occurrence of large boulders of sarsen which have been found in them, one of which was examined, and measured nearly 12 feet in circumference. Such a determination is also precluded by the much higher horizon of the outlier of the Bagshots at Harrow Hill, which is only about 2½ miles distant in a direct line.

Of what age, then, are these and the underlying beds? It is to be observed that similar deposits are found on Horsington Hill, and on high ground at Harlesden and Willesden sandy loam is traceable, which suggests the same kind of deposits. On Dollis Hill, Neasden, lately visited by the Association,* there was a shallow excavation (not deep enough, however, to fully determine the age of the bed) in which gravel and loamy deposits were found which appear to indicate a similar bed. Something of the same kind is also found on the high ground at Hendon.

---

* *Vide supra*, p. 148-152.

Taking the foregoing facts into consideration, and also that the stratified deposits on the Mount are only divided on the south side by a belt of probably denuded London Clay, about ⅜ of a mile wide, from undoubted high-terrace river-drift gravel, &c., containing flint implements, they may well be regarded as of Post-Pliocene age—older than the highest bench of river-drift in this neighbourhood.

No mollusca or organic remains of any kind have been found in them, but the constituents of the gravel seem to be largely derived from the Bagshots intermixed with moraine matter or glacial drift, transported and redeposited.

It is highly probable that such glacial drifts were widely spread over the northern part of the Thames Basin in Post-Pliocene times before the present valleys were eroded, and that in the great denudation and removal of matter which has since taken place the larger proportion of such accumulations has disappeared, and much of that which is left may be of the nature of a washed-out or *remanié* deposit.

The large number of rolled pebbles contained in the furrows, many of which are black and derived either from the Lower Eocene or Bagshots, suggests their having been torn up by ice and subsequently transported and redeposited under considerable pressure as the ice masses melted, leaving them jumbled up together with the sandy loam in as little order as any boulder-clay deposit. Such a hypothesis does not involve the occurrence of large icebergs—it is more probable that large masses of coast- and shore-ice were detached from the ice mantle in milder seasons, as well as that originating in the north, and they may have been the agents by which the material has been transported.

However we may speculate on this part of the subject, we are met with the fact that stratified beds are here found at and above the 210 foot contour, and this leads to the demonstration that at the period when these beds were formed almost all the country between the Chalk hills of Hertfordshire and Surrey, and extending, perhaps, beyond the least elevated ground in those counties, was either wholly submerged and so formed a great tidal estuary, or else a lake or chain of lakes. Professor Phillips* has shown us that an estuary or sea loch, into which most of the present tributaries of the Upper Thames flowed, once extended as high up the basin of the Thames as Reading, and even beyond. A submergence of even 250 feet in this area would produce that result ; and there is good ground for believing that a subsidence in the land exceeding that amount must have taken place in the Pleistocene period.

It appears probable that these stratified beds were deposited when the land was gradually rising, and after the period of greatest submergence of the Thames Basin ; in fact, as the waters became shallower, though still subject to tidal action. The laminated warp now seen in the wide tidal estuary of the Humber may afford us a parallel for this conjecture.

The observations of Professor Phillips indicate that a system of lakes subsequently existed in the higher reaches of the Thames, both above and below Oxford. Such lacustrine formations may very well have followed the retiring sea, as the uprise in the land continued in this part of the Thames Basin also.

If, then, the stratified deposits before us were not formed in an estuary, they may be due to a lake extending over a large part of Middlesex at a subsequent period. The latter hypothesis is strengthened by the occurrence of the finely laminated matter of which they are composed, pointing to its deposition in tranquil water.

If it is admitted that the boulder clay and moraine matter which is now found at Finchley, Watford, &c., of which there are also traces in isolated patches on the higher ground from Finchley in a S.W. direction to the Mount and Hanger Hill, and which is known to overlie pebbly gravel, &c., was once spread over much of the intervening land ; such an accumulation of detrital matter may have formed barriers and dammed up the waters of the wider river of the past when the present valleys had not been formed. This damming up may very well have been aided by the large masses of ice which, as we have seen from the evidence arising from the furrows and their contained detritus, were then floating about obedient to the winds, currents, and tides. The loamy clay and stratified beds may, in fact, be the equivalent of the Finchley moraine matter, redeposited and altered by running water.

---

* 'Geology of Oxford and the Valley of the Thames.'

The true river-drift formed even higher than the 125-foot contour, on the south of the ridge, belongs probably to the next stage, or the formation and erosion of the Thames Valley itself within the basin. That the wider river of the past was rapid in its course, and generally more torrential in its flow, is shown by the larger stones which constitute the lowest deposits of the high terrace. With such strong currents depositing matter at about the same level as the lowest extension of the assumed lacustrine beds, it is quite conceivable that the barriers forming such lakes could be finally swept away, causing much denudation and the rapid transport of glacial gravel. Lyell points out that the bursting through of such accumulations of moraine matter in floods is not an unusual circumstance. The entire absence of shells may be accounted for by the violent disturbance of the beds by ice, combined with the intensity of the cold which then prevailed. Lyell also cites the rarity of shells in glacial lakes, and says that in some Norwegian and Icelandic fiords the waters of the sea are so freshened and chilled by the melting of the icebergs that the fish are driven away and the mollusca killed. It is noticeable that there is the same absence of shells in the highest river-terrace, while at the lower level of the mid-terrace deposits at Brentford, during the formation of which it is believed a milder climate was beginning to prevail, a large number of testacean and other fossils have been found.

A vote of thanks was here accorded to Mr. A. Fraser, engineer to the Grand Junction Water Company, for the facilities he had afforded to the Director and the Members of the Association for viewing the sections, and also to Mr. Phillips, engineer in charge for Messrs. Lucas and Aird, the contractors for the work, for his kindness in furnishing the Director with the results of the trial-borings and a plan of the ground, etc.

After visiting Perivale churchyard and inspecting the tomb, the iron rails of which are embedded in the trunk of a tree, and otherwise twisted out of shape by the growth of others, the party continued the walk to the summit of Horsington Hill. Here the Director addressed the Members upon the changes which have taken place in the face of the country, in the Miocene, Pliocene, and Pleistocene periods, which could only be realized by mentally endeavouring to reconstruct it as it appeared in the Middle Tertiary epoch. A collection of fossils from the London Clay, found in making exca vations on Castlebar Hill and the Mount, had recently been added to his collection. They were obtained from the level of about 155 feet, and are believed to belong to the third or middle zone, as defined by Professor Prestwich. Among them are the following:—

Modiola elegans.
Corbula globosa.
Cardium, sp.
Pecten, sp.
Cytherea, sp.
Nucula.
Teredo.
Rostellaria (*ampla?*)
Fusus, sp.
Pleurotoma, several spp.
Natica, 2 spp.
Nautilus imperialis, &c.

Mr. A. Ramsay, F.G.S., described some years since some fossils from a sandy bed of a few inches in thickness in the Montpelier Road, Ealing, which is at about the same horizon as the above. Among them were numerous specimens of *Natica* and *Pyrula*, associated with a bed of *Modiola elegans*; an assemblage of forms which indicated, he thought, a depth in the Eocene Sea, at the period when the mollusca were living, of from 20 to 80 fathoms. The fossils occur, in his opinion, about 290 feet above the basement bed of the London Clay. Traces of the Roman occupation have lately been discovered on the Mount—portions of seven cinerary urns and a patera of Samian, besides fragments of ruder pre-Roman pottery having been obtained from there. The Director's large collection of Palæolithic and Neolithic implements, savage weapons, &c., as well as his general geological collection, were afterwards examined by the Members. In the first series were the Palæolithic implements—flakes and worked blocks of flint, in all about 600 objects, found on the Workshop Floor, Acton—as well as many flint implements from N.W. Middlesex, &c.

EXCURSION TO GOMSHALL, NETLEY HEATH, AND CLANDON.

SATURDAY, JUNE 25, 1887.

Director: H. HUTCHINS FRENCH, F.G.S.

(*Report by* THE DIRECTOR.)

On alighting at Gomshall Station, the attention of Members was directed to the exposure of fine bright-yellow sands (Folkestone Beds, Lower Greensand), which are here worked for use in building, making bricks, &c.

Following the road to Shere, keeping the Tillingbourne on the left-hand and the Chalk escarpment on the right, till the road opposite the post-office is reached, the party ascended the escarpment by Colekitchen Lane. A small exposure of Folkestone Beds was seen on the left; about 100 yards further on a pit in Gault Clay (not visited) was passed on the right, and beyond this several small pits by the roadside in Lower Chalk. Just beyond where the 400 feet contour line is marked on the map, a pit on the left-hand is in Melbourne Rock. This was carefully examined, but yielded no fossils. It was stated, on the authority of Mr. J. F. Bennett, that exposures of this division bed between the Lower and Middle Chalk show that it is continuous between this point and Reigate.

Colekitchen Farm is situated in a beautiful Coombe, and just before descending it good views are to be had over the Gault valley and Lower Greensand hill as far as Hindhead to the west and over Leith Hill, to the east. Passing on through the beautifully wooded district of the King's Woods, the summit of the Chalk was reached. Here the Ridgeway Road, a wide open grass glade stretching for miles east and west, was crossed, and woods again entered. As the descent of the northern dip-slope of the Chalk began, the path ran through a plantation of finely-grown beeches, down to Honeysuckle Bottom, which is skirted on the west by a plantation of fir-trees, known as Mountain Wood. At the northern end of this wood a halt was made, and as the party rested under the shade of the trees, the Director explained a change which the officers of the Survey had found necessary in the mapping of the geology of the district. The alteration related to the extent of ground covered by the large tertiary outlier on Netley Heath. As marked, it extended too far east and south. On re-examination it had been found to cover about one-third only of the space at present shown on the map, and to consist of three detached outliers; the largest in Hook Wood, with a smaller in Barnet Wood to the south-west, and a third small patch at Pobley Farm to the north-east. A considerable stretch of "Sands of Doubtful Age" would be marked resting on the Chalk and occupying the area of the rest of the outlier, as at present mapped, extending beyond it south and eastwards nearly as far as Green Dene Farm. The main feature of this visit was to see exposures of these sands, of gravel and associated beds in Hook Wood, and the well at Clandon.

Patches of these "Sands" occur along the North Downs from Folkestone to this, their present most westerly known extension. To what formation they belong has long been debated without any generally accepted solution having been arrived at. In Professor Prestwich's paper "On the Sands and Iron Sandstones of the North Downs," in 'Q.J.G.S.,' Vol. xiv (1858), pp. 321-335, they are claimed as the equivalents of the lowermost (Coralline Crag) beds of the Pliocene of East Anglia. Mr. Whitaker, writing in 1871 on "The Geology of the London Basin" ('Geol. Surv. Mem.,' Vol. iv, Part 1, pp. 336-342), is inclined to place them low down in the Eocenes as overlapping masses of the Woolwich and Oldhaven series.

So the question rested until last year, when Mr. Clement Reid published in "Nature" (12th Aug., 1886) the result of his investigation of the beds at Lenham, which thoroughly corroborates Professor Prestwich's view. Speaking of the fossil evidence, Mr. Reid says: "There is not a single Eocene species among them. With two or three exceptions they are all known Pliocene forms, some are new to England, though occurring in France and Italy." The Crag age of the Lenham Beds may now be regarded as established. Professor Prestwich is of opinion that the other patches of Sands of the North Downs, though they differ in character from the Lenham Beds, are all of the same age. As none of them have yielded fossils, the conclusion must be received with some reserve, although other considerations tend to confirm this view. The position of these beds, on the summit of the Chalk Downs, 600 feet above sea-level, indicates that the great valley of the Weald has been excavated since Pliocene times, the Sands having, in all probability, been derived from the denudation of a Lower Greensand island which existed where the Wealden valley now is.

The following sections were then examined :—

I.—Sand-pit S.W. of Fir Plantation (near B.M., 591-2 on 6in. Ordnance Map).

1. Brick-earth, replaced in parts by mottled clay, flint gravel, and sand, pocketing irregularly into the underlying sands, shallow bands of sub-angular flints and pebbles, frequent at the junction... ...	From 0ft. 0in. to 4ft. 0in.
2. Yellow-brown ferruginous sands, apparently false-bedded...	Seen to 6ft. 6in.

This section showed that the sands were of earlier date than the "drift," and later than the Lower Tertiaries, which occur within half a mile of the pit and differ from them in colour and lithological character. In reply to Rev. A. Irving, who claimed them as Bagshots, it was pointed out that they occurred at a lower level than the Tertiaries of the district, and as the London Clay was believed to be present in Barnet Wood (within three-quarters of a mile west, at an elevation of 674 feet), the suggestion would imply considerable contemporaneous erosion. In the absence of fossil evidence, it was impossible to determine their age within the above limits; but regarding them as the equivalents of the Lenham Beds they would be classed as Crag.

II.—Pit N.W. end of Fir Plantation, about 540ft. above Ordnance Datum.

1. Capping of soil	a few inches.
2. Brown clayey sand enclosing two irregular masses (4ft. × 1½ft. and 8½ft. × 1¼ft.) of red-blue mould clay (apparently derived from Woolwich and Reading beds)	1 to 6 feet.
3. Ochreous sands	just seen.

The excavation is not sufficiently deep to allow of the connection between Beds 2 and 3 being made out with certainty, but Bed 2 appears to cut and pocket into Bed 3.

Bed 2, on the other side of the pit, contains rounded flint pebbles and "pebbles" of chalk, some of the latter being 6in. long, though generally smaller.

III.—Gravel Pit on summit of hill in Hook Wood, on road from Woodcote Lodge to Fuller's Farm, about 678ft. above Ordnance Datum.

1.	Capping of mottled clay, sand, and flint gravel, irregularly mixed up, and in more or less wavy lines	5ft.
2.	Irregularly waved band of gravel cutting into underlying bed	From 1in. to 1ft.
3.	Compact clay (? brickearth) with small broken angular pieces of white flint and a few "nodules" of chalk 6in. long...	3ft. 6in.
4.	Gravel composed of small (white) well-rounded flint pebbles, with a large admixture (disseminated through the mass) of medium-sized and very large water-worn flints	3ft. 6in.
5.	Hard brown clayey sand	1ft. 0in.
6.	Gravel alternating with light-coloured sand,* much obscured by talus. The limits of each division consequently undeterminable	About 6ft.

Skirting Hook Wood, a small exposure of Woolwich and Reading Beds was seen in a pond at Fuller's Farm. Continuing round Barnet Wood, where mottled clay is to be seen, Merrow Downs were crossed, whence fine views across the Thames Valley are obtained when the atmosphere is clear, and Clandon was reached in time to view the spoil-heaps of the well which has been sunk for the Woking Waterworks Company. By the courtesy of the contractors, Messrs. Quill, we are enabled to give the following sections from particulars supplied by their foreman, Mr. Langton, who kept a most careful diary of the strata passed through as the work proceeded.

IV.—Section of Clandon Well (Woking Waterworks Company).

1.	Soil	2ft. 0in.
2.	Flints and yellow loamy clay	5ft. 0in.
3.	BLUE (LONDON) CLAY...	224ft. 0in.

Thirteen bands of Septaria were passed through (some of the nodules measured more than 5ft. across.)

Black loamy sand and a little water	at 30ft.	from the top of the clay.
A few pebbles and a little water	at 121ft.	
Traces of sand	at 133ft.	
Veins of sand with water	at 138ft.	
Veins of sand with water	at 143ft.	
Veins of sand	at 203ft.	
Reddish clay	at 215ft.	
Few shells...	at 219ft.	

Basement bed, well-rounded black pebbles ... ... 0ft. 6in.

---

* The sands are well seen in rabbit-holes on the south side of hill.

beds, on the summit of the Chalk Downs, 600 feet above sea-level, indicates that the great valley of the Weald has been excavated since Pliocene times, the Sands having, in all probability, been derived from the denudation of a Lower Greensand island which existed where the Wealden valley now is.

The following sections were then examined :—

I.—Sand-pit S.W. of Fir Plantation (near B.M., 591-2 on 6in. Ordnance Map).

1. Brick-earth, replaced in parts by mottled clay, flint gravel, and sand, pocketing irregularly into the underlying sands, shallow bands of sub-angular flints and pebbles, frequent at the junction... ...	From 0ft. 0in. to 4ft. 0in.
2. Yellow-brown ferruginous sands, apparently false-bedded...	Seen to 6ft. 6in.

This section showed that the sands were of earlier date than the "drift," and later than the Lower Tertiaries, which occur within half a mile of the pit and differ from them in colour and lithological character. In reply to Rev. A. Irving, who claimed them as Bagshots, it was pointed out that they occurred at a lower level than the Tertiaries of the district, and as the London Clay was believed to be present in Barnet Wood (within three-quarters of a mile west, at an elevation of 674 feet), the suggestion would imply considerable contemporaneous erosion. In the absence of fossil evidence, it was impossible to determine their age within the above limits; but regarding them as the equivalents of the Lenham Beds they would be classed as Crag.

II.—Pit N.W. end of Fir Plantation, about 540ft. above Ordnance Datum.

1. Capping of soil	a few inches.
2. Brown clayey sand enclosing two irregular masses (4ft. × 1½ft. and 8½ft. × 1¼ft.) of red-blue mould clay (apparently derived from Woolwich and Reading beds)	1 to 6 feet.
3. Ochreous sands	just seen.

The excavation is not sufficiently deep to allow of the connection between Beds 2 and 3 being made out with certainty, but Bed 2 appears to cut and pocket into Bed 3.

Bed 2, on the other side of the pit, contains rounded flint pebbles and "pebbles" of chalk, some of the latter being 6in. long, though generally smaller.

III.—Gravel Pit on summit of hill in Hook Wood, on road from Woodcote Lodge to Fuller's Farm, about 678ft. above Ordnance Datum.

1.	Capping of mottled clay, sand, and flint gravel, irregularly mixed up, and in more or less wavy lines	5ft.
2.	Irregularly waved band of gravel cutting into underlying bed	From 1in. to 1ft.
3.	Compact clay (? brickearth) with small broken angular pieces of white flint and a few "nodules" of chalk 6in. long...	3ft. 6in.
4.	Gravel composed of small (white) well-rounded flint pebbles, with a large admixture (disseminated through the mass) of medium-sized and very large water-worn flints	3ft. 6in.
5.	Hard brown clayey sand	1ft. 0in.
6.	Gravel alternating with light-coloured sand,* much obscured by talus. The limits of each division consequently undeterminable	About 6ft.

Skirting Hook Wood, a small exposure of Woolwich and Reading Beds was seen in a pond at Fuller's Farm. Continuing round Barnet Wood, where mottled clay is to be seen, Merrow Downs were crossed, whence fine views across the Thames Valley are obtained when the atmosphere is clear, and Clandon was reached in time to view the spoil-heaps of the well which has been sunk for the Woking Waterworks Company. By the courtesy of the contractors, Messrs. Quill, we are enabled to give the following sections from particulars supplied by their foreman, Mr. Langton, who kept a most careful diary of the strata passed through as the work proceeded.

IV.—Section of Clandon Well (Woking Waterworks Company).

1. Soil			2ft. 0in.
2. Flints and yellow loamy clay			5ft. 0in.
3. BLUE (LONDON) CLAY...			224ft. 0in.
Thirteen bands of Septaria were passed through (some of the nodules measured more than 5ft. across.)			
Black loamy sand and a little water	at 30ft.	from the top of the clay.	
A few pebbles and a little water	at 121ft.		
Traces of sand	at 133ft.		
Veins of sand with water	at 138ft.		
Veins of sand with water	at 143ft.		
Veins of sand	at 203ft.		
Reddish clay	at 215ft.		
Few shells...	at 219ft.		
Basement bed, well-rounded black pebbles			0ft. 6in.

---

* The sands are well seen in rabbit-holes on the south side of hill.

4. WOOLWICH AND READING BEDS			**83ft. 0in.**
Compact bed of shells and clay	1 ft.	2½ft.	
Compact bed of shells and limestone ...	1½ft.		
Mottled clay, blue and brown	3 ft.	66ft.	
Do. red and bluish	1 ft.		
Do. brown and blue	2 ft.		
Do. buff and brown	4 ft.		
Do. light blue and red	4 ft.		
Very dark clay, spotted brown	9 ft.		
Mottled clay, red and buff	5 ft.		
Do. pinky-red and slate ...	1 ft.		
Very hard light-blue clay	2 ft.		
Pink and light-blue clay	4½ft.		
* Mottled clay, becoming sandy towards base	30½ft.		
Hard loamy Greensand	2½ft.	14½ft.	
Hard grey yellow sand	1¼ft.		
Sandy green loam mottled brown ...	1¼ft.		
Hard Greensand, dry and loamy, with scattered shells, much broken	4½ft.		
Thin bed of small well-rounded dark flint pebbles	¼ft.		
Greenish loamy clayey sand	2ft.		
Clean grey sand full of water	2ft.		
Green-coated flints	½ft.		
To Chalk			**314ft. 6in.**

REFERENCES.

Geological Survey Map, Sheet 8.

Ordnance Survey Map, new series, Sheet 285.

WHITAKER.—"Geology of the London Basin" (' Mem. Geol. Surv.,' Vol. iv).

---

* At the depth of 269½ft. the diary was discontinued, but was resumed again at 300ft. When the well was first dug, water rose and overflowed to 10ft. above the surface of the ground.

EXCURSION TO SUDBURY, SUFFOLK.

Saturday, July 9th, 1887.

(In conjunction with the Essex Field Club.)

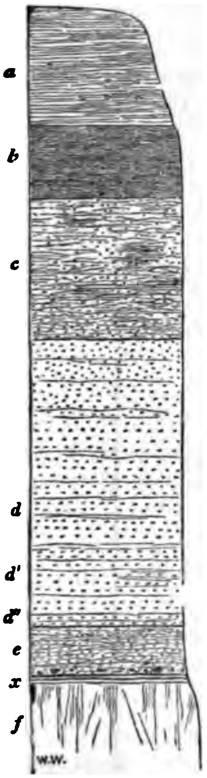
Directors: Dr. J. S. Holden and W. Whitaker, B.A., F.R.S.

(*Report by* W. Whitaker.)

The party crossed to the Essex side of the Stour, below the Railway Station, and the Director drew attention to the fact that the river was full of water, notwithstanding the long drought, explaining that this was because the supply was partly derived from

Fig. 1.—General Section of the Great Pit South of Ballingdon (Sudbury), 1873.
8 feet to an inch.

(From the 'Quart. Journ. Geol. Soc.,' Vol. xxx, 402, kindly lent by the Council of the Geological Society.)



a. Brown and dark grey stiff London Clay, with race, slipping much, a few feet.

Reading Beds.
b. Blackish sandy clay and clayey sand, 3 ft.
c. Pale greenish-grey, red-mottled bedded sandy clay, the red mottling chiefly in the upper part; the bottom part (with greengrains) fills wee tubular holes in the underlying bed, 6 feet.

Thanet Beds.
d. Buff and pale grey, fine, soft, and slightly clayey sand, firm and bedded. The bottom 3 feet or so (*d'*) of a pinkish tinge, the lowest 6 inches (*d"*) of a deeper colour, and harder; a slight intermixture of this with the top of the next bed for 3 or 4 inches, about 12 feet.
e. Clayey greensand,* very bright-coloured at top, with green-coated flints at the bottom (some large) and a few higher up, about 2 feet.

f. Chalk, with a thin layer of tabular flint, *x*, of alternate black and white layers, at top,† other flints rare—to water.

The beds are even and flat, or with a S.S.W. dip (up to 3°).

---

* This bed was noticed by W. Smith in his 'Geological Map of Essex' (1820) as "Greensand, called Devil's Dung," which name is still used in the neighbourhood.

† This layer was also noticed by W. Smith in his 'Geological Map of Suffolk' (1819) as follows:—"Chalk, covered with a Floor of Stratified Flint."

springs in the Chalk, fed by the great underground reservoir of that formation, which was not affected by drought for some time.

Passing by "The Grove," the great Chalk-pit at Ballingdon, close by, was the first section visited (Fig. 1). Here the beds seen range from the base of the London Clay down to the Chalk; but all that was done was to draw attention to the even junction of the Tertiary beds with the Chalk, to notice the presence of the Thanet Sand, and to give a short general account of the local geology. Returning to the Grove, the fine section in the brickyard was carefully examined, through the courtesy of Mr. Allen. The great pit is in a mass of Glacial Drift, that here occurs low down in the valley of the Stour, the full succession of deposits being as follows:—

Boulder Clay, up to 12 feet.

Laminated brickearth, up to 12 feet or more.

Gravel, mostly coarse, and sand, up to 10 feet or more.

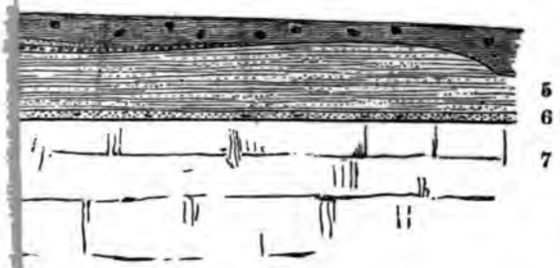
Boulder Clay, in parts sandy and gravelly, 20 feet or more.

Gravel and sand, hardened at top by calcareous cement.

These beds were seen to lie in waves, to abut against the Chalk on the west, and to sink eastward, though the Chalk sometimes rises up, and the overlying greenish base-bed of the Thanet Sand also shows occasionally. A goodly variety of stones, mostly well scratched, were noticed in the Boulder Clay, and the complexity of the Drift was appreciated.

Crossing again into Suffolk, the fine Chalk-pit (also belonging to Mr. Allen), a little eastward of Sudbury Station, was entered, and the party clambered up the spoil-heaps to get a general view of the beds above the Chalk, the more adventurous then following one of the Directors along the terrace, at times very narrow, left along the top of the Chalk. The even junction of the Thanet Sand and the Chalk was thus well seen, as also the fairly eve junction of Crag with the former, that deposit consisting of ferruginous sand, some 10 feet thick, with a gravel-base (of flin pebbles with phosphatic nodules). On the other hand the Bould Clay was seen to scoop into the Crag and the Thanet Sand (Fig. 2

The sections in the brickyard on the other side of the footpa to the east were seen to be in great part hidden, and Membe were, therefore, obliged to take on trust (or at least to seem to so) the tale told by one of the Directors as to the terrific way which the Drift was twisted about. Although he appealed drawings made years before, yet there was a semi-suppressed sm

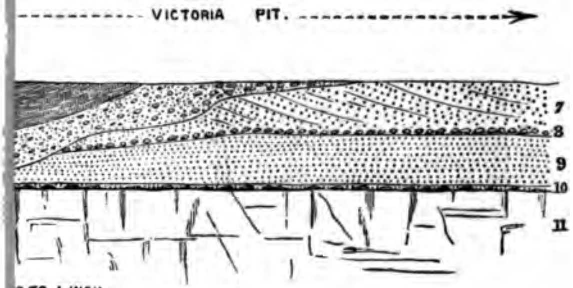


-General of the Geological Survey.)

ınd pale grey, fine, soft, firm sand, the lowest part of a pinkish ge which is deeper at the base, up to 12 feet or more.

ey greensand, brightest at top, with green-coated flints at the e, about 2 feet.

k with a very few flints. At top a thin continuous layer (up to ches) consisting of alternations of flint and chalk.



T TO I INCH

(Since joined, in accordance with the Director's predictions.)

rvey.)

n ferruginous sand [? shells in bottom part].

of flint-pebbles, flints, phosphatic nodules, &c.

soft buff clayey sand.

ey greensand, with green-coated flints, 1 to 1½ feet.

lk, bedded, worked to a depth of nearly 50 feet, slight dip (into the hill).

en lines show the connection of the beds which was considered nd has since been fully confirmed.

springs in the Chalk, fed by the great underground reservoir of that formation, which was not affected by drought for some time.

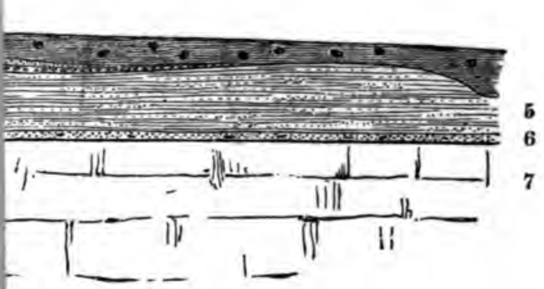
Passing by "The Grove," the great Chalk-pit at Ballingdon, close by, was the first section visited (Fig. 1). Here the beds seen range from the base of the London Clay down to the Chalk; but all that was done was to draw attention to the even junction of the Tertiary beds with the Chalk, to notice the presence of the Thanet Sand, and to give a short general account of the local geology. Returning to the Grove, the fine section in the brickyard was carefully examined, through the courtesy of Mr. Allen. The great pit is in a mass of Glacial Drift, that here occurs low down in the valley of the Stour, the full succession of deposits being as follows:—

Boulder Clay, up to 12 feet.
Laminated brickearth, up to 12 feet or more.
Gravel, mostly coarse, and sand, up to 10 feet or more.
Boulder Clay, in parts sandy and gravelly, 20 feet or more.
Gravel and sand, hardened at top by calcareous cement.

These beds were seen to lie in waves, to abut against the Chalk on the west, and to sink eastward, though the Chalk sometimes rises up, and the overlying greenish base-bed of the Thanet Sand also shows occasionally. A goodly variety of stones, mostly well scratched, were noticed in the Boulder Clay, and the complexity of the Drift was appreciated.

Crossing again into Suffolk, the fine Chalk-pit (also belonging to Mr. Allen), a little eastward of Sudbury Station, was entered, and the party clambered up the spoil-heaps to get a general view of the beds above the Chalk, the more adventurous then following one of the Directors along the terrace, at times very narrow, lef along the top of the Chalk. The even junction of the Thane Sand and the Chalk was thus well seen, as also the fairly eve junction of Crag with the former, that deposit consisting of fe ruginous sand, some 10 feet thick, with a gravel-base (of fli pebbles with phosphatic nodules). On the other hand the Bould Clay was seen to scoop into the Crag and the Thanet Sand (Fig.

The sections in the brickyard on the other side of the footp to the east were seen to be in great part hidden, and Memb were, therefore, obliged to take on trust (or at least to seem to so) the tale told by one of the Directors as to the terrific way which the Drift was twisted about. Although he appealed drawings made years before, yet there was a semi-suppressed smi

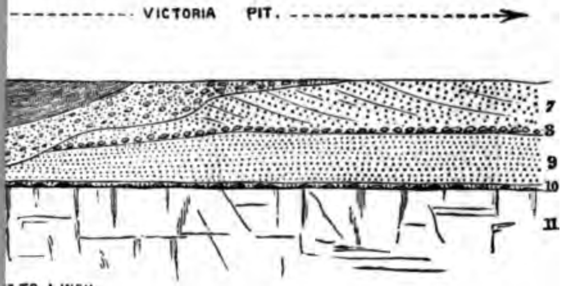


·-General of the Geological Survey.)

and pale grey, fine, soft, firm sand, the lowest part of a pinkish
ge which is deeper at the base, up to 12 feet or more.

ey greensand, brightest at top, with green-coated flints at the
e, about 2 feet.

k with a very few flints. At top a thin continuous layer (up to
ches) consisting of alternations of flint and chalk.



T TO 1 INCH

(Since joined, in accordance with the Director's predictions.)

rvey.)

n ferruginous sand [? shells in bottom part].

of flint-pebbles, flints, phosphatic nodules, &c.

soft buff clayey sand.

vey greensand, with green-coated flints, 1 to 1½ feet.

lk, bedded, worked to a depth of nearly 50 feet, slight dip
. (into the hill).

en lines show the connection of the beds which was considered
and has since been fully confirmed.

of scepticism on many faces—but that smile faded before the day was out.

The pit on the eastern side of the Cemetery again showed a deep section of Glacial Drift, Crag, and Thanet Sand above the Chalk, the topmost beds being somewhat irregular.

Passing over to the valley north-east from the town, the two contiguous pits on the south-eastern side of the road were first visited. Here the section was remarkably clear, and no one could doubt the irregularity of the Drift, or the way in which it cuts across the beds below; moreover, as when the section had been drawn by one of the Directors, some years ago, there was a gap between the pits, which had since been wholly cut away, revealing a continuous section in accordance with what that Director had suggested as likely to occur, there was a renewal of confidence in the leaders. It was seen that, whilst at the south-west there was Crag resting evenly on Thanet Sand, the latter resting still more evenly on the Chalk, on the north-east there was a mass of Boulder Clay, with some brickearth and gravel, reaching right down to the green base-bed of the Thanet Sand, and in the middle part there was, at top, a hollow of brickearth, underlain by sand and gravel, which on one side scooped into the Crag and the Thanet Sand, and on the other side into the Boulder Clay (Fig. 3).

The minds of the party having now been fairly prepared for anything that Glacial Drift could do, the little valley was crossed and Mr. Green's Alexandra Pit, on the other side, was entered, having been kept as a *bonne bouche*, for the last. Here the beds of the Glacial Drift could be seen in a state of extraordinary contortion, being sometimes vertical. Their characters, moreover, seemed changeable (Figs. 4 and 5). It was seen that the contortion could not have been caused by a force acting from below upwards, the underlying Thanet Sand and Chalk being quite even. It must have been caused, therefore, by a force from above, and that of great masses of ice, squeezing and shifting the beds, seems to be the only one available. The Members were now fairly staggered with the behaviour of the Drift, and their ideas having become sadly mixed they were ready to believe anything and everything that the Directors told them. That desirable result having been brought about they re-entered Sudbury, sadder, but wiser; their drooping spirits, however, being soon revived by a good meat tea at the Rose and Crown.

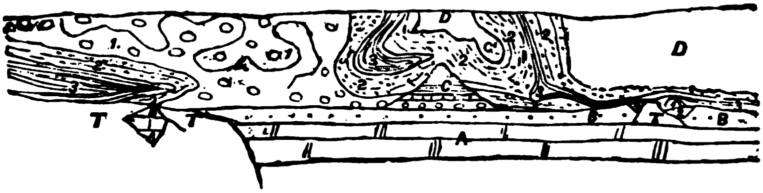


FIG. 4.—Section in Mr. Green's Pit N.E. of Sudbury. (Kindly lent by the Editor of the 'Geological Magazine.')

Length about 100 feet.

A. Chalk.
B. Thanet Sands.
C. Red Crag.
C'. Red Crag caught up in Drift.

1. Boulder Clay.
2. Gravel and Sand.
3. Loam.
D. Gravel dug over and filled in.
T. Talus.

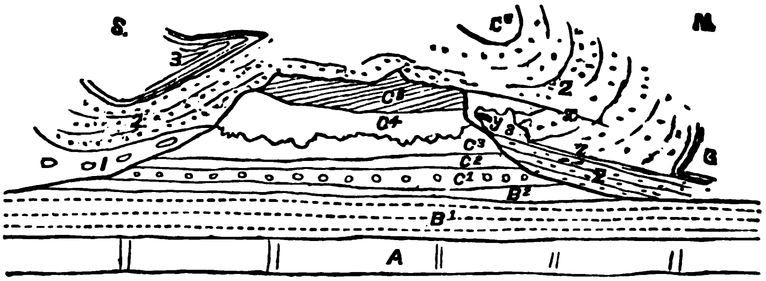


FIG. 5.—Enlargement of the Crag ridge in Fig. 4. (Kindly lent by the Editor of the 'Geological Magazine.')

A. Chalk.
Thanet Beds. { B1. Green clayey sand.
B2. Red Clay.
Red Crag. { C1. Pebble Bed.
C2. Hard dark brown very ferruginous gravel.
C3. Bleached (yellow-green) sand.
C4. Rust Red sand, not laminated.
C5. " " " very finely laminated.
C6. Bleached (yellow-green) sand in Drift.
1. Boulder Clay.
2. Gravel and sand.
3. Loam.
x. Iron-staining from Crag ridge.
y. Fragments of C2 included in Drift.
z. Marked divisional plane (fault ?).

Afterwards the party broke up, most Members going home, but a very small party going on with Mr. Whitaker to Bury St. Edmunds, where they put up at the Angel, of Pickwickian fame.

Next day this select few saw some of the sections of brickearth and gravel near Bury, in which flint implements had been found, and were hospitably entertained to tea at Badwell Friary by Mr. Henry Prigg, who showed them his fine collection of worked flints from the Drift, chiefly from that neighbourhood (to the extent of some hundreds of specimens).

WORKS TO BE CONSULTED.

Geological Survey Map, Sheet 47 (Drift Edition).

Memoir on the above ('Geology of the N.W. Part of Essex,' etc., 1878), in which the Sections are described in detail. Price, 3s. 6d.

In the Memoir on the Geology of Ipswich, etc. (1884), there is a supplement on Sections at Sudbury, pp. 132, 133. Price, 2s.

MARR.—'Geol. Mag.,' June, 1887, pp. 262-270.

Members going to Bury might usefully consult Geological Survey Map, Sheet 51, S.E. (Drift Edition) and the Memoir thereon ('The Geology of Bury St. Edmunds,' etc., 1886). Price, 1s.

EXCURSION TO PLUMSTEAD AND BOSTAL HEATH.

SATURDAY, JULY 16TH, 1887.

Director: J. G. GOODCHILD, F.G.S., H.M. Geol. Survey.

(*Report by* THE DIRECTOR.)

On the arrival of the party at Plumstead Station a move was at once made to the railway-cutting adjoining, where there is a fine exposure of the beds ten or more feet each way from the junction line of the Woolwich Beds with the Thanet Sands. The Thanet Sands here consist of drab or pale fawn-coloured sands, fine in grain, generally without any very evident traces of bedding, and almost everywhere devoid of pebbles of any kind. In this part of the London Basin fossils, as a rule, are conspicuous by their absence; but on the present occasion Mr. Goodchild got out a calcareous concretionary mass from near the top of the formation here, which yielded several casts of *Cucullæa crassatina, Cardium semigranulatum, Cyprina morrisii*, and several examples of a *Modiola* seemingly different from any yet recorded from these beds in England. The Woolwich Beds (here unusually like the Thanet Sands) are distinguished by their well-defined lamination, by the presence of lines, or beds, of flint pebbles, and by their generally more loamy character. The line of junction between the two formations is clearly defined by an irregular zone of brown clay containing pebbles, which clay here, as nearly everywhere else, is curiously splashed into the upper part of the Thanet Sands.

From Plumstead Station the party moved by way of the Griffin Road to the fine exposure of the Oldhaven and Blackheath Beds on the Park Estate, bordering upon what was formerly Plumstead Common. Here the upper half of the section showed thick lenticular and false-bedded masses of well-rolled flint pebbles, which represent the Blackheath type of this deposit. The lower part of the section consists of sharp whitey-brown sand, with sparsely scattered flint-pebbles; this part of the section reproducing almost exactly the typical features of the beds at Oldhaven Gap, Herne Bay. The Director called attention to several points of minor interest in connection with these, nearly all having been noticed long since by Mr. Whitaker and others. In the roadway immediately to the north of the section Mr. Goodchild pointed out the *Cyrena*-bed of the Woolwich Series (here less clayey than usual), which happens at this point to have been spared by the denudation of the older strata resulting from the change in physical conditions that seems in so many places to have ushered in the Blackheath and Oldhaven Beds.

After examining an extensive road-cutting in the Blackheath Beds adjoining the last section, and noting the irregularity and false-bedding of their component strata, the party visited several sections in Cage Lane, where recent excavations had left the exposures in as perfect condition as could be wished. Here much discussion arose as to the geological position of a mass of pebble-beds exposed in a deep pit close to the Mission Hall, the Director having been at first disposed to regard these beds as part of the Blackheath Beds let down by the Abbey Wood fault, but having been afterwards led to regard them as talus rolled to the foot of the hill from the pebble-beds forming its summit there. A road-cutting higher up showed the Woolwich Beds very clearly, overlying the Thanet Sands, as in the railway-cutting (eighty or more feet below) which the party had just left. Near the top of the road-cutting is the junction of the Woolwich Beds with the pebble-beds of the Blackheath series, which form the whole of the plateau of the Common above.

When the party had arrived at Plumstead Common attention was called to the origin of the plateau, which there, and elsewhere in the neighbourhood, had resulted from the exposure by denudation of a large area of the original upper surface of the Blackheath Pebble-beds. The London Clay there had clearly been stripped back a considerable distance from the present outer edge of the sheet of pebbles it once covered; while the denuding force that effected the removal of so large a mass of the clay had left the pervious mass of pebble-beds so exposed, nearly intact. Rain, frost, and wind all seem to produce no effect whatever upon the upper surface of a stratum of this nature. The chief denudation that has affected these beds takes the form of deep, steep-sided, square-edged gullies, or " slades," as they are called. These appear to represent the modified descendants of streams whose initiation dates back at least as far as the time when the London Clay extended all over this part. Some of these slades are certainly older than the brick-earths. Springs, representing the rain-water held up by the first impervious bed below the Blackheath Beds, seem to be the chief agents now at work in undermining the edges of these strata, and several examples of their action were noted on the way.

Opposite Woolwich Cemetery the large sand-pit behind Hope Cottage was examined. Here the whole of the Lower London Tertiaries, from the top of the Blackheath Beds down to the sheet of green-coated flints on the top of the Chalk, could be examined at one view. Mr. Jacobs, the proprietor, very obligingly cleared the lowest part of the section, so that the whole could be seen. The chief feature of interest in the section is the evidence of the removal by denudation of nearly the whole of the Woolwich Beds at this point, before the deposition of the pebble-beds of the next series above. It is evident, from a study of this section and others in North Kent, that what stratigraphical break there is above the Chalk is here in the Lower London Tertiaries themselves, and is not at their base, where its existence seems to have been assumed rather than to have been proved. Mr. Whitaker has long since pointed this out. So far as the palæontological aspect of the question is concerned, the Director was disposed to regard the Thanet Sand fauna as a modified descendant of that of the Gault; less certain forms that remained elsewhere after the close of the Cretaceous period; and less certain others (such as the *Cephalopoda*) which appear to have been exterminated, or to have been driven to distant localities, by the advent of the colder climate characterizing the Thanet Sands period.

In the pit at Hope Cottage attention was directed to the "trail," the Pleistocene beds capping part of the section there being looped and crumpled, much as they are at Erith and Crayford, &c. The pit also showed good examples of intrusive sheets and veins of Pleistocene loam, which the Director regarded as having worked down into the Eocene strata through ruptures caused by the impact of floating masses of ice acting upon the frozen surface of the strata when the Thames (&c.) was dammed back by a southward extension of the Scandinavian Ice Sheet at the close of the Glacial Period.

From Hope Cottage the party wended their way past Wickham brick-pit, through the grounds of Mr. Russell, of Manor Farm, and thence, after a pleasant stroll through the shady walks of Old Park Wood, noting many features of interest by the way, to th place where an *al fresco* tea had been provided. Then, after vote of thanks had been passed to Sir Julian Goldsmid, Mr. Russell and Mr. Jacobs, for leave granted to enter their respectiv properties, the party broke up and returned home.

REFERENCES.

Geological Survey Map, Sheet 1, S.W. (Drift Edition).
WHITAKER.—'Geology of the London Basin,' &c.

EXCURSION TO SHEPPEY.

MONDAY, AUGUST 1st, 1887.

Director: W. H. SHRUBSOLE, F.G.S.

(*Report by* THE DIRECTOR.)

Being Bank-Holiday it need scarcely be said that the trains we behind time ; consequently Warden Point was not reached t fully an hour after the time contemplated. In the course of th seven-mile drive the ancient Abbey Church at Minster, which dat from the year 664, was passed ; and, shortly before reachin Warden, Shurland Hall, built by Sir Thomas Cheney, in the reig of Elizabeth, was a very noticeable feature in the landscape. A Warden the road terminates at what is left of the parish churc yard, the principal part having gone by degrees to lower levels.

The party then descended to the beach and commenced searchin for fossils on the clayey slope, whilst travelling westward. A the eastern boundary of the cliff, the beach is generally nearly quite destitute of shingle, as the high-level gravel which fal from above is rapidly and continuously moved westward, and unless intercepted by groynes, or removed, it only comes to rest at Garrison Point, Sheerness, where the accumulation is noticeably narrowing the mouth of the river Medway.

It is useless to search for fossils *in situ*. The better way is to look for them in the dark patches of pyrites that will be noticed on the beach. The larger things, such as *Nautili*, Turtles, and Crocodilian remains, are generally found at the foot of the beach slope. Besides fossils and pyrites, septarian nodules will be seen littered about in great abundance. These, when calcined and ground, make Roman cement, which seems to have been nearly superseded by the so-called "Portland" cement. By cracking some of these nodules beautiful crystals of barytes (heavy-spar) may be obtained.

At Hensbrook Gap a halt was made, whilst a supply of recent specimens of Sheppey fruits and other refreshments received due attention. The fossils that had been found were here compared and identified. A fine group of stems of *Graphularia Wetherellii* was the most noteworthy object, as it is extremely rare both here and at other parts of the London Basin. Mr. Shrubsole was called upon to give a short sketch of the salient geological features of the locality, and would have complied had it not been necessary to hurry on towards East-End Lane *en route* for Sheerness.

Shortly after leaving Hensbrook the lighter tinted loams and sands of the Lower Bagshot series were seen as a thin line at the top of the cliff section. Farther east the sands increase gradually, till at East-End Lane they attain a thickness of about 30 feet. The lines of bedding are nearly horizontal. At certain seasons of the year some of the layers are faced with cryptogamic plants, the appearance of which might lead a careless observer to conclude, wrongly, that beds of brightly coloured sands were intercalated with those of duller hue.

Reluctantly the beach was forsaken in order that better progress might be made on the cliff path. After taking tea at the Royal Hotel, Sheerness, the party left for London about seven o'clock. The time available for scientific purposes was considerably reduced at both ends by the late arrival and the early return.

REFERENCES.

Geological Survey Maps, Sheets 2 and 3.
WHITAKER, W.—'Memoirs of Geological Survey,' Vol. iv, part 1.
Reports of Excursions to Sheppey, in 'Proc. Geol. Assoc.,' iv, p. 320; vii, p. 149.

EXCURSION TO CORNWALL.

MONDAY, AUGUST 8TH, TO SATURDAY, AUGUST 13TH, 1887.

Directors : THE PRESIDENT; WILLIAM THOMAS, F.G.S., Secretary to the Mining Association and Institute of Cornwall; and A. K. BARNETT, F.G.S., of Penzance.

(*Report by* THE PRESIDENT.)

As this was the first occasion on which a visit of the Association to the West of England had been extended beyond the Tamar, an unusually large number of Members and friends availed themselves of the advantages afforded by the Excursion. Most of the party travelled from London to Truro on Saturday, August 6th, and these had not struck far into Cornwall before an interesting rock presented itself for examination. An opportune halt for half an hour at Menheniot Station enabled the party to leave the train and examine the well-known serpentinous rock to which their attention had been directed by Mr. W. Semmons. A quarry of this rock close to the station afforded specimens of what is sometimes known as the "Clicker Tor Serpentine"—a rock which has been described by Mr. J. A. Phillips,* Mr. S. Allport,† Mr. Collins,‡ Mr. Teall,§ and Prof. Rosenbusch.‖ It is regarded by Mr. Allport as an intrusive mass of olivine-dolerite partially converted into serpentine, while Prof. Rosenbusch considers that the original rock was a picrite. Its microscopic structure is well figured by Mr. Teall, who describes its character as that of an altered "ophitic dolerite (diabase), in which olivine was present in great abundance and felspar only to a very small extent."—'Brit. Pet.,' Pl. II., Fig. 2.

Monday.—The real work of the week commenced early on Monday morning, when the party assembled at the Royal Institution of Cornwall, in Pydar Street, Truro. Here they were cordially received by Mr. Nicholas Whitley, F.G.S., Vice-President, Major E. Parkyn, Hon. Sec., Mr. H. Thomas, Mr. Howard Fox, and several other representative members of the Institution. The formal reception took place in the lecture room, where Mr. Whitley occupied the chair. After welcoming the party, the Chairman gave a general sketch of the geology of Cornwall, and called attention to the distribution of flint flakes and shattered flints in the county. Major Parkyn supported the Chairman in extending a welcome to the Association. Mr. Howard Fox then described the serpentine and associated rocks of the Lizard district, of which he had brought a fine display of specimens for exhibition to the meeting. The courteous reception having been duly acknowledged by the President, who also expressed his appreciation of the instructive addresses which had been delivered, the party visited the Museum under the guidance of the representatives of the Institution previously named.

---

* 'Phil. Mag.,' xli, 1871, p. 100.

† 'Quart. Journ. Geol. Soc.,' xxxii, 1876, p. 422.

‡ 'Geol. Mag.,' Dec. 3, Vol. iii, 1886, p. 364.

§ 'British Petrography,' 1886, p. 124.

‖ 'Mik. Phys.,' Bd. ii, 1877, p. 530.

Those of the party who cultivated a taste for mineralogy manifested keen interest in the collection of minerals. This collection had been arranged and catalogued some time back by Mr. J. H. Collins, F.G.S. Among Cornish minerals special note should be made of the fine specimens of native gold from the Carnon steam works, the native silver from Fowey Consols, and the native copper from the Lizard and other localities in the west. The series of Cornish cassiterites, including such forms as "sparable tin" and "rosin tin," is at once fine and extensive. The Cornish fossils collected by the late Mr. C. W. Peach also attracted due attention. But the glory of the Museum lies in its antiquarian treasures. Here is to be seen the unique ingot of ancient tin, dredged up about sixty years ago near St. Mawes, at the entrance to Falmouth Harbour, and supposed to be one of the "astragali" mentioned by Diodorus Siculus. The late Sir Henry James explained the shape and size of this peculiar block as being specially convenient for transport in boats from Iktis to Gaul, and thence on horseback overland to Marseilles.* Here, too, is the little bronze image of a bull found in St. Just, and regarded as a relic of Phœnician intercourse.† But perhaps the most generally interesting objects in this department are the two gold *lunulæ* or penannular ornaments found in 1863 at Harlyn, near Padstow. The cinerary urns unearthed from various tumuli, the implements in stone and bronze, with the stone moulds for casting bronze celts, and the blocks of " Jews' tin " or masses of metal from the ancient " blowing houses " of Cornwall, were among the many local objects which gave special interest to the visit to the Truro Museum.

---

* 'Note on the Block of Tin dredged up in Falmouth Harbour,' by Col. Sir Henry James, R.E. Stanford: 1863.

† Figured in Robert Hunt's 'British Mining,' 1884, Fig. 2, p. 15.

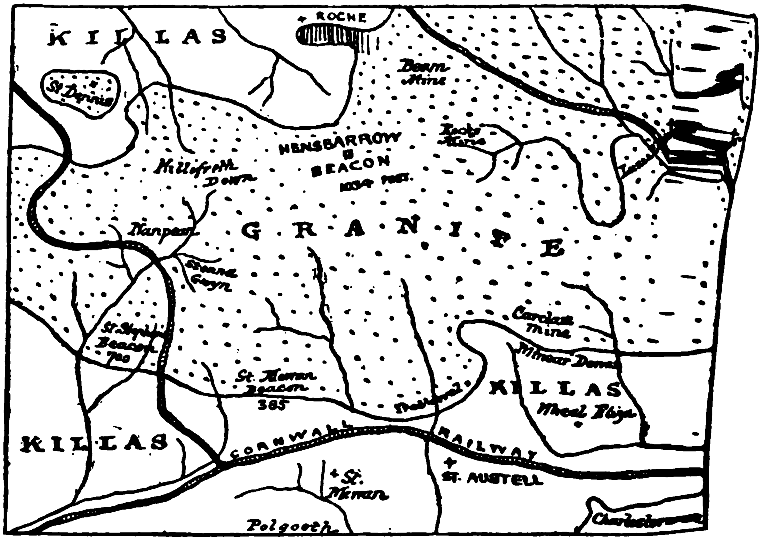


FIG. 1. Map of the country north of St. Austell visited on Monday, August 8. Scale, half an inch to one mile. The Hensbarrow Granite is dotted; the schorl-rock of Roche is indicated by vertical shading; and the Killas left blank.

On leaving Truro by rail for St. Austell the party was joined by Mr. J. J. Beringer, F.C.S., Lecturer to the Mining Association and Institute of Cornwall, who had come from Camborne to assist in conducting the Excursion. On reaching St. Austell the Members were received by Mr. R. H. Williams, F.G.S., under whose guidance they proceeded in conveyances to Carclaze mine, about two miles north of St. Austell. Here, in the midst of a broad expanse of waste land, commanding an extensive and picturesque view, the visitors found themselves in the presence of a vast open excavation, about a mile in circuit. Worked at the present time chiefly for China-clay, this pit was originally opened as a tin mine, the decomposed granite, or " soft growan," being traversed by veins of cassiterite, or tin-stone, associated with schorl or black tourmaline. Mr. Williams sketched the history of the mine and described the present method of working. It is probably the oldest excavation in Cornwall, its history stretching back for five centuries. According to the late Mr. R. Symons it occupies an area of 13 acres, and reaches a depth of 132 feet.[*]

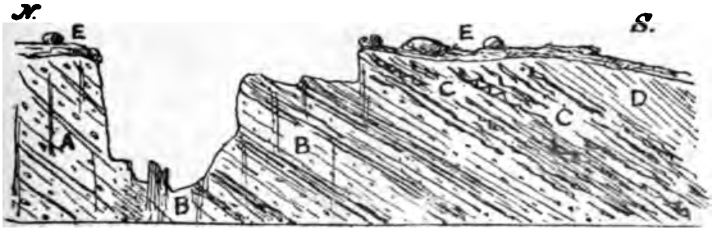


Fig. 2. Section of Carclaze Old Pit. (J. H. Collins.) Visited on Monday, August 8.

A. Rather hard Granite, with thin schorl veins, some dipping south, and others vertical.
B. China-clay rock, or Carclazite, with schorl veins, and veins of Quartz and Greisen.
C. Tourmaline schist, gradually passing into D.
D. Reddish and brownish Killas, or Clay-slate.
E. Overburden, containing and capped by loose boulders.

From Carclaze the party proceeded to Minear Downs, an open work, where branches of tin-ore are seen traversing the Killas or clay-slate. Having returned thanks to Mr. Williams for his courteous assistance, and to Messrs. John Lovering and Co. for permission to visit the pits at Carclaze and Minear Downs, the party returned to St. Austell, and after being refreshed by luncheon started in conveyances to the extensive workings of the West of England China-clay Company, near Nanpean. Here they were met by Mr. Stocker, jun., who conducted the party over the works and explained in detail the several operations of preparing the clay. In formally thanking the proprietors and those who had rendered their services on this occasion, the President, responding to the wishes of the party, entered at some length into the subject of the nature and origin of China-clay and China-stone.

The discovery of China-clay, or Kaolin, in England dates from about the year 1750, when William Cookworthy, of Plymouth, having seen certain samples of the clay and of the china-stone, which had been brought from America, found similar materials at Tregonning Hill, in the West of Cornwall, and at St. Stephen's, in the Hensbarrow district. The Chinese names by which these substances came to be known—*Kaolin* and *petuntze*—were due to the Père d'Entrecolles, a French Jesuit, settled in China, who sent to Réaumur, in Paris, samples of the materials used by the Chinese in their porcelain manufacture. It appears, however, that his names are not those generally applied to similar substances in China.* Cookworthy, using the local phraseology, called the petuntze or China-stone "growan" or "moor-stone," while the Kaolin he described as "growan clay." With these materials he made experiments on the production of hard-paste porcelain at Plymouth,† and sought to establish its manufacture at Bristol.

---

[*] For recent descriptions of Carclaze pit see 'The Hensbarrow Granite District,' by J. H. Collins. Truro: 1878, p. 36. Also 'Geology of Cornwall,' by Brenton Symons. London: 1884, p. 140; and a paper "On Carclaze Tin and China-clay Pit," by R. Symons, in 'Journ. R. Inst. Cornwall,' Vol. vi, 1881, p. 140.

The China-stone is a granitic rock, composed generally of quartz, white felspar (partially decomposed), and gilbertite. This rock Mr. Collins distinguishes as *Petuntzite.* The rock from which China-clay is prepared is a granite in a much more advanced state of alteration, the felspar having been converted into kaolin, or pure clay : it consists of quartz, kaolin, and mica ; the Cornish rock generally containing two micas. As the China-clay rock is well seen in the "soft growan" of Carclaze, Mr. Collins has termed it *Carclayzite.* The method of washing the clay from the rock is described in his paper recently read before the Association (*vide supra*, p. 111).‡

It will thus be seen that the essential difference between the carclayzite and the petuntzite lies in the fact that in the former the felspar has not been completely kaolinized, and therefore still retains some of its alkaline silicate, which confers fusibility upon the rock, while the Kaolin itself is practically infusible. It is consequently to the China-stone that porcelain owes its translucency; it is this that forms what the Chinese call the "flesh" of the ware, while the clay constitutes its "bone." Specimens of China-stone, fused to a vitrified mass, were distributed to the party as an illustration of the properties and use of this material.

---

* See 'Histoire et Fabrication de la Porcelaine Chinoise,' by M. Stanislas Julien. Paris, 1856.

† "William Cookworthy and the Plymouth China Factory," by R. N. Worth, F.G.S., 'Trans. Devon Assoc.,' Vol. viii, 1876, p. 480.

‡ See also Mr. Collins's 'Hensbarrow Granite,' which contains detailed information and bibliographical references respecting China-clay and stone (pp. 10 to 36).

The alteration of the granite is popularly attributed to the action of carbonic acid in meteoric waters, but there are considerable difficulties in accepting so simple an explanation, and those who have given most attention to the subject are inclined to believe, as maintained by M. Daubrée, that hydrofluoric acid, or other fluorides, must have been the chief agent in attacking the felspar.* The presence of compounds containing fluorine, such as tourmaline, lepidolite, and fluor-spar, is very common in China-clay districts. Fine examples of fluor-spar, presenting a deep amethystine tint, were found by the party when examining the China-stone quarried at the West of England works.

In compliment to the Association, the Royal Institution of Cornwall had kindly organized an evening conversazione, at which the members of the two bodies had an opportunity of becoming acquainted with each other. The geologists were very courteously received by the Rev. W. Iago, M.A., the President; Mr. H. M. Jeffery, F.R.S., Vice-President; Major Parkyn, Hon. Sec., and a large party of members. After tea and coffee had been served, the party adjourned to the lecture room, where the President of the Institution took the chair, and offered a formal welcome to the Association, accompanied by an invitation to join in the annual autumn excursion, which would this year be to the neighbourhood of Bodmin. The reception and invitation were gratefully acknowledged by the President of the Association. Mr. E. A. Wünsch, F.G.S., then delivered an address, in which he expressed his views on the nature of metamorphism, and on the origin of the Lizard serpentine. A discussion ensued, in which the Association was represented by the President, Dr. Foulerton, and Colonel McMahon. Some sections of Cornish rocks were exhibited under the microscope by Mr. Thomas Clark; and other objects of scientific interest were brought forward by members of the Royal Institution, thus contributing to render this meeting one of the most pleasant gatherings during the week of the Excursion.

Tuesday.—Those of the party who were not afraid of a long day's work on Tuesday paid an early visit to the Cathedral works, where they were received by Mr. Robert Swain, the Clerk of the Works, who pointed out the different kinds of stone employed in this structure. The following note on this subject is taken from a recent paper by Mr. R. N. Worth, F.G.S.* :—"The exterior ashlar work is of Mabe granite, the interior ashlar of St. Stephen's stone (China-stone), a form of aplite; the body of the walls being filled in with local walling stone—killas, chiefly from Ideless, near Truro. The vaulting shafts in choir and transepts, and also in the baptistry, are principally Polyphant, with Duporth stone in some instances, and some Duporth is also introduced in the shafting in the triforium. The small arcade on the east wall of the south transep will contain a series of shafts of red porphyry from Carnsew Stithians, given by the late Colonel Somers Cocks; and serpentine is also to be introduced. Pentewan, Wild Duck, Newnham and other elvans were used partially by way of experiment restoring the lower part of old St. Mary's ornate south aisle." addition to these local stones, use has been made of oolitic limestones from Bath, from Doulting, in Somersetshire, and fr Northamptonshire; as also of "Frosterley Marble," a bl variety of Carboniferous Limestone, rich in fine corals, from ne Stanhope, in Durham. Much interest was taken in t material from Duporth, concerning which Sir W. W. Smyth h remarked that it "had been brought into use in the Cathedral wi great effect for columns and other purposes, and it might hold its head and claim to be quite as handsome and suitable to th purpose as the Purbeck marble that was found in churches in othe parts of the country."†

---

* See 'Études synthétiques de Géologie expérimentale,' par A. Daubrée. Paris, 1879, p. 29.

At 9.27 the party left Truro by rail, and on arriving at Car Brea Station were met by Mr. William Thomas, who had organize the arrangements for the day, and by a number of other gentleme representing the Mining Association and Institute of Cornwall The party was now divided—one group going with Captain C. Bishop to East Pool Mine, and another with Captain W. T. Whi to Wheal Agar, while the bulk of the party ascended Carn Bre Those who went underground were unable to rejoin the princip party until the afternoon. The Carn Brea division—conducted Captain Josiah Thomas, of Dolcoath, Captain Teague, of C Brea Mine, and Mr. W. Thomas—having made their way to summit of this rugged hill of grey granite, 738 feet high, w

---

* "The Rocks and Minerals of Cornwall and Devon," 'Fifty-four Annual Report of the R. Corn. Polytech. Soc.,' 1886, p. 74.

† 'Fifty-fourth Rep. R. Corn. Polytech. Soc.,' 1886, p. 26.

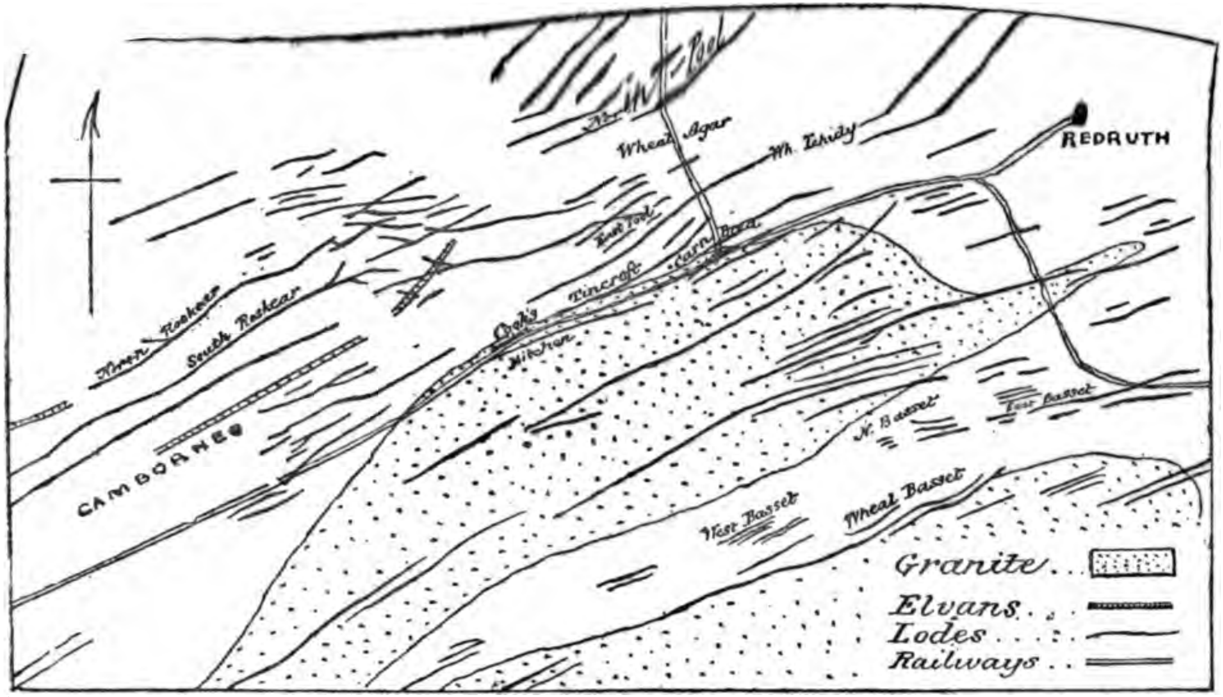


FIG. 3. Map of the country between Redruth and Camborne, showing the mines in the neighbourhood of Carn Brea, visited on Tuesday, August 9. Scale 1½ inch to 1 mile. (From Moissenet, after Mr. R. Symons.) In this map the name of Dolcoath has been accidentally omitted. The mine is situated a little to the East of Camborne.

ewarded for the rather toilsome ascent by a magnificent view stretching across the country from sea to sea. The principal features of interest in this panorama were pointed out by the Directors, who called attention to the connexion between the physical characters of the country and its geological structure[illegible] Splendid examples of weathered granite were presented by th[illegible] spheroidal boulders and fantastically-worn rocks on this hill; an[illegible] discussion arose as to the formation of those rock-basins, logan[illegible] stones, and other objects which the early antiquaries of Cornw[illegible]ll regarded as monuments of Druidical worship.

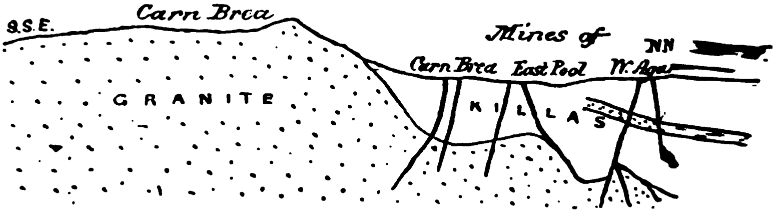


FIG 4. Section of Granite and Killas, with Lodes, near Carn Brea. (Moissenet.) Scale, $\frac{1}{21120}$.

Before leaving the summit of Carn Brea the excursionists we[illegible]re invited by Captain Teague to partake of refreshments, which [illegible]e had thoughtfully ordered to be carried up the hill by a party [illegible]f *bal maidens*, an invitation which, under the mid-day sun of a sultry August day, was gratefully accepted. After descending t[illegible]e hill, the visitors inspected the surface-workings of Carn Bre[illegible], Tincroft, Cook's Kitchen, and Dolcoath. At Cook's Kitch[illegible]n Captain Charles Thomas kindly distributed some specimens of t[illegible]e ores of the district, and at Dolcoath Captain Josiah Thom[illegible]as entered into a full description of the surface-machinery, and of t[illegible]he operations on the dressing floors. A substantial luncheon w[illegible]as provided at Dolcoath, and, in replying to a vote of thanks for th[illegible]is hospitality, Captain Josiah Thomas gave some interesting deta[illegible]ils respecting this extraordinary mine. Dolcoath was started in 17[illegible]9, and is now about 420 fathoms deep. The mine is something l[illegible]ke three-quarters of a mile in length, and out of this piece of grou[illegible]nd there has been already returned copper to the value of £3,500,0[illegible]0, and tin to the value of nearly £3,000,000. The total outlay [illegible]ad been £40,000, and the annual profits were now about £50,0[illegible]0. The number of hands employed at Dolcoath is about 1,350.

The party was now reinforced by those who had spent the mor[illegible]ing underground, and who returned delighted with their subter[illegible] ranean experiences; nor were they less warm in acknowledging the courtesy of Captains Bishop and White, who had not only shown them every attention below, but had provided for their entertainment above ground. As the conditions under which the ores of tin and copper occur in Cornwall and the method of working them are well explained in Mr. Collins's paper,* it is needless to refer to the subject here. Sufficient to say that the interest of the party in Cornish mining was much enhanced by several valuable papers on the subject, which had been obligingly sent by Dr. C. Le Neve Foster, F.G.S., for distribution among the party.

In the afternoon the geologists had the privilege of meeting the members of the Mining Association and Institute of Cornwall, whose President (G. L. Basset, Esq.) had invited the two bodies to a banquet at Tehidy Park. About 170 sat down in the magnificent rooms of this mansion. It unfortunately happened that illness prevented Mr. Basset from being present, but his place was efficiently taken by Mr. T. Elliot Boog. After the usual loyal toasts had been proposed and honoured, Mr. G. J. Smith gave "The Bishop, Clergy, and Ministers of all Denominations," to which the Rev. Canon Rogers replied. Mr. R. H. Williams then proposed, in complimentary terms, "The Geologists' Association," which was duly responded to by the President. Mr. T. V. Holmes next proposed "The Mining Association and Institute of Cornwall," to which Captain Josiah Thomas returned a felicitous reply. Finally, Captain Henderson proposed "The Health of Mr. Basset," which was suitably acknowledged by Mr. Boog.

The principal rooms of the mansion having been visited after luncheon, most of the Members strolled through the beautiful grounds until a start was made in open carriages for Hayle. This long ride enabled the Members to appreciate the fine scenery of the North Coast of Cornwall, and halts were made from time to time in order to allow of a closer examination of the rocks. The cliffs of slaty rocks rise at some places sheer from the sea to a height of 300 or 400 feet. Much interest was also taken in the hills of blown sand at Godrevy and Gwithian. Hayle Station was reached in time for the last train to Penzance, where the party took quarters for the remainder of the week.

Wednesday.—At ten o'clock on Wednesday morning the geologists left Penzance for St. Erth, where they were anxious to examine the Pliocene deposits which, since their discovery in 1882, have been the subject of considerable discussion. At St. Erth Station the party was met by Mr. G. Bown Millett, Hon. Secretary of the Royal Geological Society of Cornwall, and by Mr. Fortescue W. Millett, F.G.S., of Marazion, who, having specially studied the St. Erth beds, had kindly consented to describe them. Later in the morning the geologists had the advantage of being accompanied by Miss Goodman, a lady resident at St. Erth, who has paid great attention to the local fossils.

---

* 'Sketch on the Geology of Cornwall and West Cornwall.' *Supra*, p. 101

The following note on the Pliocene deposits of St. Erth has been obligingly furnished by Mr. Robert W. Bell, F.G.S. :—*

"The St. Erth Pliocene beds were first noticed about five years ago in the course of excavation for clay used for puddling the Penzance dock which was then building. The clay may be seen in one corner of the large Sand Pit close to, and belonging to, the Vicarage of St. Erth.

"The upper portion consists of that deposit which is almost universal in West Cornwall, and is known as 'Head.' It is clayey, and crammed with angular pieces of killas and other local rocks. Beneath the head is yellow sand, in one part of which could be seen last year some evidence of the crumpling up of the bed similar to that prevalent in some of the Glacial Deposits over the crags of the Eastern Counties.

"Below this is clay, the upper part yellow without fossils, and the lower blue with shells, getting more numerous towards the base. The most numerous are *Turritella*, a large *Nassa*, and, at the lower fossiliferous portion, numbers of small *Cerithia*. The clay is also very rich in Foraminifera, and spicules of Holothurians and Tunicates. About 150 species of Mollusca, mostly small, have been obtained from careful washing of the clay.

"Below this is a bed of Quartzose Sand resting upon Elvan."

After the Association had arranged to visit this locality it was found that the section was no longer visible, and that it would require considerable labour to prepare a fresh posure. This work was kindly undertaken by the Royal Geological Society of Cornwall, who, having with some difficulty obtained permission for the visit, went to the expense of employing labourers to cut a new section in view of the visit of the London geologists. The visitors consequently found themselves in the presence of a fine, fresh exposure of the fossiliferous beds, and the more zealous members of the party came away enriched with its spoils.

---

* While these sheets were passing through the press the Reporter heard with extreme regret of the death of this accomplished conchologist.

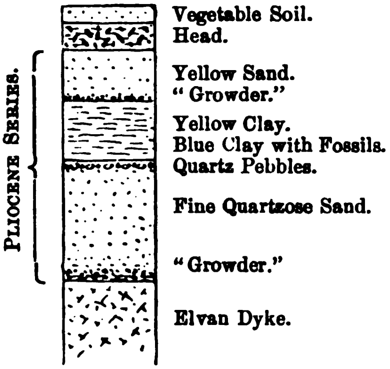


FIG. 5. Section at St. Erth, 1885. (Kendall and Bell.)

Mr. Fortescue Millett, in describing the fossils of St. Erth, dwelt especially upon the foraminifera, since it is these to which he has given special attention. He has recognized no fewer than 120 distinct forms, of which five are extinct and 115 now living in various seas. The extinct species are *Lagena margino-radiata*, *Globigerina cretacea*, *Rotalia punctato-granosa*, *Faujasina carinata*, and *F. orbignyi*. Of the living species 92 are found in the British seas. The following nine forms are here found fossil for the first time, namely :—*Bolivina robusta*, *B. tortuosa*, *Cassidulina bradyi*, *Discorbina patellæformis*, *D. wrightii*, *Truncatulina tenuimarga*, *Rotalia dentata*, *Polymorphina concava*, and *Spirillina limbata*, var. *decorata*. It is noteworthy that *Textularia quadrilatera*, which occurs here, has been found fossil in the Pliocene deposits of Kar Nicobar, and is now living in the Canaries and Cape de Verde Islands, but occurs most abundantly in the South Pacific.*

From St. Erth the party returned by rail to Marazion, where they were met by Sir W. W. Smyth, F.R.S., the President of the Royal Geological Society of Cornwall. Sir Warington and Lady Smyth hospitably entertained the excursionists at their country residence overlooking Mount's Bay, and in the afternoon accompanied them to St. Michael's Mount. After pointing out by the way such features as were of special interest to geologists, Sir

---

* "Additional Notes on the Foraminifera of the St. Erth Clay," by ortescue William Millett; 'Trans. R. Geol. Soc. Cornwall,' 1886.

Warington selected a suitable position on the southern side of the mountain base, where he delivered an admirable address on the geological and mineralogical characteristics of the Mount.

The lecturer first called attention to the junction of the granite with the killas, and to the metamorphism which the latter had suffered by this contact. Both the granite and the killas were intersected by a system of veins, well displayed at the spot where the party had assembled. Some of these veins were of granite, which, when in a condition of greater or less fluidity, had been injected into cracks in the slaty rocks, and these veins had been the subject of discussion as far back as the time of Sir H. Davy and Dr. Boase. In addition, however, to these granitic veins the rocks presented a series of mineral veins, some of which, being stanniferous, were veritable tin-lodes in miniature. These veins presented a very noteworthy parallelism, cropping out in east and west lines, two or three feet apart, with almost mathematical regularity. The granite in the immediate neighbourhood of the veins has been converted into a granular rock, consisting chefly of quartz and mica, and strongly resembling the Greisen of the tin-miners in Saxony. Quartz was the most common constituent of the veins on St. Michael's Mount, but associated with the quartz were a number of fluorine-bearing minerals of much scientific interest. One of these was lepidolite, or lithia-mica—a mineral which occurs characteristically in the tin-lodes of Altenberg, in Saxony, and Zinnwald, in Bohemia. Sir Warington dwelt upon the similarity of conditions under which tin-ore occurs at St. Michael's Mount, and in the mines of the Erzgebirge, between Bohemia and Saxony. The resemblance is supported by the occurrence of topaz at the Mount, a mineral which contains as much as 17 per cent. of fluorine, and which also occurs in Saxony, especially in the well-known topaz-rock of the Schneckenstein, and in the columnar variety found at Altenberg, and distinguished as *pycnite*. The topaz now found at St. Michael's Mount is in the form of colourless crystals, so small as to be recognized only with difficulty. Beryl likewise occurs, as also apatite, fluor-spar, and tourmaline. Of metallic minerals he noted the abundance of wolfram, associated in places with wolfram ochre; while there were also present mispickel, or arsenical pyrites, copper-pyrites, and, above all else, cassiterite or tin-stone. Sir W. W. Smyth pointed out the similar association of many of these minerals with tin-ores in other parts of the world, and referred to M. Daubrée's ingenious explanation of such paragenetic relations by assuming that the group of minerals had been deposited by the decomposition of various fluorides derived from deep-seated sources in the earth's interior. Crystallized oxide of tin is obtained by passing a current of stannic chloride (or fluoride ?) with steam through a red-hot tube. The reaction of the fluorides on the granite would probably give rise to most of the common associates of tin-ore as suggested by the experiments in which Daubrée produced artificial apatite and topaz.[*] After Sir W. W. Smyth had concluded his instructive discourse he conducted the party to the best spots for observing the phenomena which he had been describing. Later in the day most of the Members visited Lord St. Leven's Castle, picturesquely seated on the summit of the Mount, and thus forming the apex of this great pyramidal boss of granite. After bidding a grateful farewell to Sir Warington and Lady Smyth the excursionists returned to Penzance.

Thursday.—At nine o'clock on Thursday morning the party assembled at the Museum of the Royal Geological Society of Cornwall, where they were received by Mr G. Bown Millett, Hon. Sec., Mr. A. K. Barnett, F.G.S., Hon. Curator (who acted as conductor throughout Thursday and Friday), and Mr. Ambrose Taylor, Assistant Curator. These gentlemen, accompanied later on by Mr. Thomas Cornish, were unsparing in their attention to the visitors. The ground-floor of the Museum is devoted to the collection of fossils, which was arranged in 1878 by Mr. Etheridge, F.R.S., and includes a fine series of Silurian and Devonian fossils from Cornwall, collected chiefly by the late Mr. C. W. Peach. The extensive mineral collection is located on the upper floor, and is arranged on the principle adopted in the Museum of Practical Geology. Here the visitors had an opportunity of inspecting to great advantage the minerals of the county, including the rarer species, as also a collection of local rocks. The educational value of the Museum is greatly enhanced by the system of clearly labelling the specimens and by the publication of an excellent guide-book.[†]

[*] For Daubrée's collected papers on this subject see his 'Etudes synthétiques de Géologie expérimentale,' 1879. See also Sir W. W. Smyth's "Remarks on the Geology of St. Michael's Mount," in 'Trans. Min. Assoc. and Inst. of Cornwall,' Vol. i, 1887, Part iii, p. 132; and Dr. C. Le Neve Foster's "Remarks upon the Tin-Deposits of East Wheal Lovell," in 'Trans. R. Geol. Soc. Cornwall,' Vol. ix, 1876, Part ii.

[†] 'Guide to the Museum of the R. Geol. Soc. of Cornwall, Penzance,' by C. Le Neve Foster, B.A., D.Sc., F.G.S., and A. K. Barnett, F.G.S. 1880. 8vo., pp. 15. Price one penny.

Before leaving the Museum the President of the Association took occasion to thank the Society not only for the privilege of inspecting the Collections, but for the great aid which it had rendered to his party in connexion with the St. Erth pit. He reminded those present of the excellent work which had been accomplished by the Society since its formation in 1811, as attested by its publications, including the valuable treatises of the late Mr. W. J. Henwood; and while recalling the past he heartily wished the Society an equal measure of prosperity in the future.

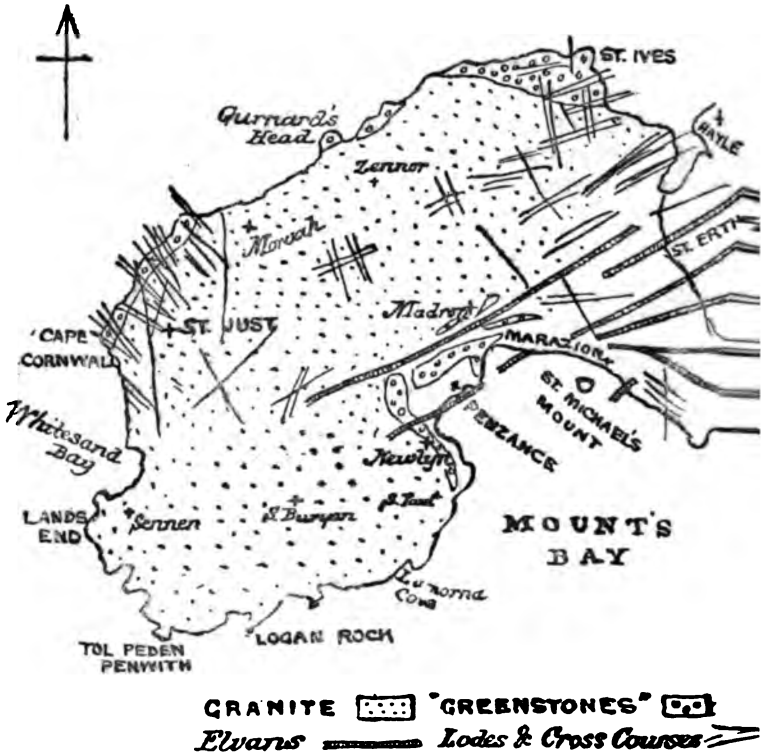


FIG. 6. Map of the Western extremity of Cornwall, including the distr visited on Wednesday, Thursday, and Friday, August 10th, 11th, a 12th. Scale, 1 inch to 4 miles.

The excursionists then took carriages for St. Buryan, where they visited the church (*temp* Hen. VII.) and the ancient stone crosses. Thence they drove to Treryn, and after luncheon walked down to the cliffs, in the neighbourhood of the Logan Rock. In this magnificent headland they had an opportunity of studying the behaviour of granite when exposed to marine action and to subaërial denudation. Meteoric agencies operating along the joints of the granite had first divided it into cuboidal masses, and then, rounding these blocks, had produced the phenomena of rocking or logan stones. The ease with which the great stone, weighing upwards of 60 tons, can be made to rock was practically illustrated by the more adventurous spirits of the party, who climbed to the very summit of the pile of rocks and set the ponderous mass in oscillation. A brief description of the rock was given by Mr. Barnett.

After walking for some distance along the cliffs, a descent was made to the beach at Porthgwarra to inspect an interesting passage worn in the picturesque rocks, to which attention had been called by Mr. Thomas Cornish.

Then ascending the cliffs a short walk brought the party to *Tol Pedn Penwith*, or the "Holed Headland of Penwith," a promontory which takes its name from the large tunnel-like chasm in the granite opening below into the sea. From this interesting spot a journey was made, partly on foot and partly in conveyances, to the Land's End—the extreme western point of England—whence the party drove back to Penzance.

The object of the day's excursion had been to acquire familiarity with the peculiarities of granite scenery—both inland and along the coast—scenery which, to many of the party, presented much novelty.

Friday.—Early on Friday morning the party visited Messrs. Bolitho's smelting works at Chyandour, permission having been courteously granted by the proprietors. In consequence of a family bereavement, Mr. T. S. Bolitho was unable to be present, but in his absence every attention was paid to the visitors by Mr. A. K. Barnett, the manager, who conducted the party through the works and explained the successive stages in the operations of smelting and refining tin. A charge of dressed ore, or "black tin," mixed with culm, is thrown into a reverberatory furnace, and, from time to time, well stirred with a rabble; in about six hours from the time of charging, the furnace is tapped, and the metal, or "white tin," is run out, accompanied by slag. The charging of one furnace and the tapping of another were witnessed. The operation of refining this crude tin is effected on the hearth of a reverberatory furnace, where the blocks are subjected to liquation. The more fusible tin is run out into a huge cast iron "kettle," in which the metal, kept hot by a fire beneath, is subjected to "poling." This process caused much amusement. A large billet of green apple-wood, held by a crutch, was introduced into the molten tin, which immediately commenced to "boil," the tin being splashed about in all directions. The dross was then skimmed off and the refined metal ultimately ladled into moulds, where it consolidated into ingots, bearing the brand of the works. Pieces of tin stamped with the well-known "lamb and flag" of Chyandour were brought away as interesting souvenirs of this very instructive visit.

At the gates of the tin-works carriages were waiting to convey the party to Carne, whither they had been invited by Charles C. Ross, Esq. The object of this visit was to inspect the magnificent collection of minerals in Mr. Ross's private museum. This building contains the historical collection of Cornish minerals, originally formed by Mr. Joseph Carne, and augmented by the late Miss Elizabeth Carne, to whom the arrangement of the mineral collection in the Penzance Museum is also largely due. Important additions to the Carne Museum have likewise been made from time to time by judicious purchases by its present owner. The visitors were most cordially received at Carne by Mr. and Mrs. Ross, and after admiring the beautiful grounds and partaking of refreshments, which had been generously provided, they proceeded to the inspection of the Museum. Here the mineralogists were particularly interested in the fine specimens of minerals obtained many years ago from St. Michael's Mount, and from various Cornish mines long since abandoned, including many specimens of surpassing beauty and extreme rarity. Nor had the more recent discoveries in Cornwall been neglected, as witnessed, for instance, by the fine Henwoodite from West Phœnix Mine, and the magnificent Diallogites from St. Just. The party, before leaving, expressed their sincere pleasure at this visit and their grateful acknowledgment of Mr. and Mrs. Ross's hospitality.

From Carne a long drive westwards, over a plateau of grey granite, presenting some wild moorland scenery, brought the party to the little mining town of St. Just. A short walk thence led to the fine cliffs of Cape Cornwall, where some interesting examples of contact-metamorphism were studied. Under the guidance of Mr. Barnett, accompanied by Mr. W. Thomas, Mr. Herbert W. Smyth, and others familiar with the locality, the excursionists made their way along the cliffs to the surface-workings of the famous submarine mines of Botallack and Levant. At Levant they were received by Captain White, who explained the mining machinery, including the "man-engine," or apparatus for the descent and ascent of miners. By his permission, too, they overhauled the parcels of ore upon the floor of the mine, and thus secured specimens not only of the ordinary yellow copper-ore, or chalcopyrite—some of which was brilliantly iridescent, forming the attractive "peacock-ore"—but also of the rarer ores—copper-glance, or redruthite, and "horse-flesh ore," or erubescite.

A descent was then made towards the shore in order to gain a better view of the magnificent cliffs which are traversed by the outcropping copper and tin-lodes. These veins not only seam the exposed rocks, but pass thence under the Atlantic, whither the adventurous miner has followed them for a considerable distance. The hornblende-rocks in this neighbourhood are notable for containing a store of interesting minerals, such as axinite, garnet, and epidote; but failing to secure these rarities the geologists had to remain content with having seen representative specimens in some of the museums which they had visited in the county. From Levant they walked towards St. Just, and thence drove home to Penzance.

Saturday.—An early start on Saturday morning was rendered necessary by the long drive which had been arranged to the district of the Lizard. At Helston a short halt was made. In

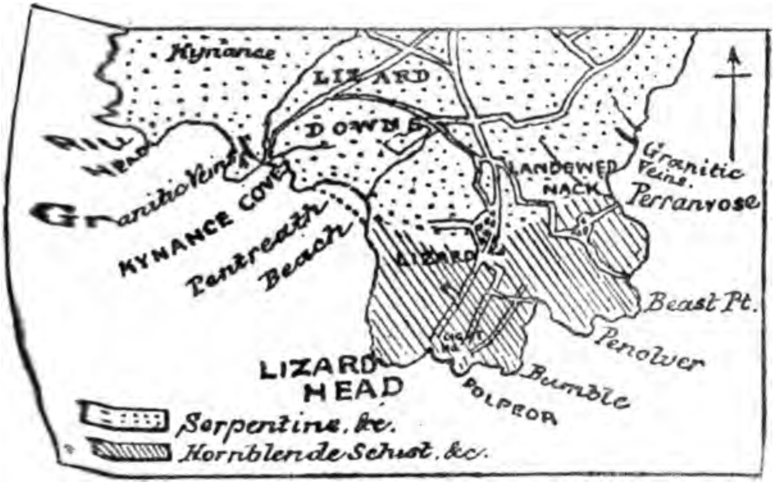


FIG. 7. Map of the Lizard District, visited on Saturday, August 13th. Scale, 1 inch to 1 mile.

e course the wild downs of the Lizard district were approached, e beautiful little Cornish heath (*Erica vagans*) announcing the resence of serpentine.

At Lizard town the excursionists were met by Mr. Howard Fox, F.G.S., of Falmouth, and Mr. E. A. Wüncsh, F.G.S., of Carharrack, who had kindly undertaken to act as conductors. The party here broke up into two groups, one under the guidance of each Director, but they practically visited the same spots. A walk through Landewednack took them to the junction of the hornblende-schist with the serpentine, and at the Balk quarry specimens of serpentine were freely collected. They then descended to the shore and inspected the granulitic, or banded crystalline series, and the gabbros of Pen Voose or Perranvose. Mr. J. J. H. Teall had obligingly furnished the party with copies of his geological map of this district on the 25-inch scale. He had also previously favoured them with the following note, referring to the chief features which were likely to be visited during the day's excursion:—

"The dominant rock at Kynance Cove is an olivine-hornblende serpentine. Granite veins occur in the serpentine. About the Lizard Head several varieties of rock may be collected. A corrugated actinolitic schist is one of the most interesting. The rocks here have evidently been affected by intense mechanical forces. On the shore at Polpeor bosses and lenticles of greenstone (sometimes porphyritic) occur in association with green actinolitic schists. A corrugated mica-schist is also present in considerable abundance, as well as other rocks which it is difficult to name.

"Between Polpeor and Church Cove the cliffs are formed almost exclusively of hornblende-schist. Many varieties of this rock may be collected, some well banded and rich in epidote, others massive and resembling a diorite.

"North of Church cove serpentine sets in, and good specimens may be collected from the Balk quarries. At Pen Voose, north of the serpentine quarries, the serpentine is succeeded by the 'granulitic series' of Prof. Bonney, and on the north side of Pen Voose granite veins, mica-diorite, gabbro, and serpentine are exposed. Transitions from massive gabbro to a gabbro-schist may be here observed."

It was found desirable, through the state of the tide, to reverse this programme, but nevertheless all the chief points were visited at some time or other in the course of the day. The last spot was Kynance Cove, which appropriately completed the Excursion as the *bonne bouche* of the week's work.

After a substantial meal at Kynance Cove the usual complimentary speeches were made by the President, Mr. Spratling, B.Sc., and Mr. T. V. Holmes. The purport of these was to tender the thanks of the Association to all who had assisted in the organization of the week's Excursion, especially to the local leaders, without whose welcome help the arrangements could never have been successfully carried out.

On Saturday evening the party formally broke up, but some of the more ardent geologists, bent on unravelling, if possible, the intricacies of the Lizard rocks, remained in the district for some time and enjoyed the advantage, day after day, of visiting the principal points of interest under the guidance of Mr. Howard Fox and Mr. Wünsch. Ultimately they bent their way homewards, not simply laden with heavy loads of minerals and rocks, but carrying away the most pleasant recollections of their visit to the West country, while they left behind them a legacy of sincere gratitude for the cordiality with which they had been everywhere received by their Cornish friends.

REFERENCES.

Geological Survey Maps, Sheets 31, 32, 33.

Ordnance Maps (New Series), Sheet 358 (Land's End).

Allport, S.—"On the Metamorphic Rocks surrounding the Land's End Mass of Granite," 'Quart. Journ. Geol. Soc.,' xxxii, 1876, p. 407.

Argall, W. H.—"On the Elvan Courses of Cornwall," 'Miners' Assoc. Corn. and Devon for 1875,' p. 37.

Barnett, A. K.—"Elvan Courses of Cornwall," 'Miners' Assoc. Corn.,' 1873, p. 69.

Bell, R. G.—"The Pliocene Beds of St. Erth," 'Trans. R. Geol. Soc. Cornwall,' Vol. xi, 1887, p. 45.

Bonney, Rev. Prof. T. G.—"On the Serpentine and Associated Rocks of the Lizard District; with Notes by W. H. Hudleston," 'Quart. Journ. Geol. Soc.,' xxxiii, 1877, p. 884.

——— 'The Hornblendic and other Schists of the Lizard District,' *Ibid.*, xxxix, 1883, p. 1.

Collins, J. H.—'On the Hensbarrow Granite District,' 1878.

——— "The Geological Age of Central and West Cornwall," 'Journ. Roy. Inst. Cornwall,' Vol. vii, 1883, p. 18. Part ii (with H. F. Collins), Vol. viii, 1884.

——— "On the Mining District of Cornwall," 'Proc. Inst. Mech. Eng.,' 1873, p. 89.

——— 'Handbook to the Mineralogy of Cornwall and Devon,' 1871.

De la Beche.—'Report on the Geology of Cornwall, Devon, and West Somerset,' 1839.

Foster, Dr. C. Le Neve.—"On the Great Flat Lode south of Redruth and Camborne," 'Quart. Journ. Geol. Soc.,' Vol. xxxiv, 1878, p. 640.

——— 'On some Tin Stockworks in Cornwall,' *Ibid.*, xxxiv, 1878, p. 654.

Harrison, W. J.—'The Geology of the Counties of England and Wales,' 1882, pp. 37 to 44.

Henwood, W. J.—"On the Metalliferous Deposits of Cornwall," 'Trans. Roy. Geol. Soc. Cornwall,' Vol. v, 1843.

Hunt, Robert.—"Treatise on British Mining," 1884.

Kendall, Percy F., and Bell, R. G.—"On the Pliocene Beds of St. Erth," 'Quart. Journ. Geol. Soc.,' Vol. xlii, 1886, p. 201.

Maynard, J.—"Carn Brea Hill," 'Miners' Assoc. Corn.,' 1873, p. 43.

Millett, Fortescue W.—"Notes on the Foraminifera of the St. Erth Clay," 'Trans. R. Geol. Soc. Cornwall,' 1886.

Moissenet, Prof. L.—"Observations on the Rich Parts of the Lodes of Cornwall," translated by J. H. Collins, 1877.

Phillips, J. A.—"On the Chemical Composition and Microscopic Constitution of certain Cornish Rocks," 'Phil. Mag.,' Feb., 1871.

——— "The Rocks of the Mining Districts of Cornwall," 'Quart. Journ. Geol. Soc.,' xxxi, 1875, p. 319.

——— 'On the so-called Greenstones of Western Cornwall,' xxxii, 1876, p. 155.

——— 'A Treatise on Ore Deposits,' 1884.

Reid, Clement.—"The Pliocene Deposits of North-Western Europe" (For St. Erth beds). 'Nature,' xxxiv. Aug. 12, 1886, pp. 341-343.

Semmons, W.—"The Metallic Ores of Cornwall," 'Soc. Amateur Geol.,' Vol. 1, No. 1, 1888.

Smyth, W. W.—"On St. Michael's Mount," 'Trans. Mining Assoc. and Inst. of Cornwall,' Vol. i, Part iii, 1887, p. 132.

Somervail, A.—"On the Geological Structure and Age of the Strata of South Cornwall," 'Journ. Roy. Inst. Cornwall,' vii, 1883, p. 262.

Symons, Brenton.—"Treatise on the Geology of Cornwall," in 'Gazetteer of Cornwall,' by R. Symons, Penzance, 1884.

Teall, J. J. H.—"The Metamorphosis of the Lizard Gabbros," 'Geol. Mag.,' 1886, p. 481.

——— Chapter on Serpentine in 'British Petrography,' 1886, p. 104.

Thomas, Josiah.—"Dolcoath Main Lode," 'Miners' Assoc. Corn. and Devon for 1883,' p. 13.

Ussher, W. A. E.—'The Post-Tertiary Geology of Cornwall,' 1879.

Whitley, Nicholas.—"The Effect of Geological Structure and the Action of the Waves on the Geographical Outline of Cornwall," 'Trans. R. Geol. Soc. Corn.,' Vol. vii, 1852, p. 220.

——— "Indications of Glacial Action in Cornwall," 'Journ. R. Inst. Cornwall,' No. xi, 1870, p. 184.

Wood, Searles V.—"On a New Deposit of Pliocene Age at St. Erth," 'Quart. Journ. Geol. Soc.,' Vol. xli, 1885, p. 65.

Woodward, H. B.—'Geology of England and Wales,' Second Edition, 1887, pp. 75, 139, 575, 576, 579.

Worth, R. N.—"The Rocks and Minerals of Cornwall and Devon," 'Fifty-fourth Annual Rep. of the R. Corn. Polytechnic Soc.,' 1886.

N.B.—The references given above include only a few of the more important and recent sources of information respecting that part of Cornwall which was visited by the Association. The 'Transactions of the Royal Geological Society of Cornwall,' commenced in 1818, offer a valuable repertory of information on local geology. A list of works from the year 1602 to 1873, including the titles of 654 books, papers, maps, &c., bearing upon the geology, mineralogy, and palæontology of Cornwall, prepared by Mr. W. Whitaker, will be found in the 'Journ. Roy. Inst. Cornwall,' Vol. v, No. 16, p. 61.

ON THE UNMAKING OF FLINTS.

BY PROFESSOR JOHN W. JUDD, F.R.S., F.G.S.

(*Read Friday, May 6th,* 1887.)

The subject of the *making* of flints is one which has been not unfrequently discussed at meetings of the Geologists' Association, and it is not necessary for me to do more than refer to the valuable summary of what is known upon the question from the pen of Professor T. Rupert Jones, F.R.S., who has contributed many original and suggestive observations of his own to the discussion of the problem.* What I wish to call attention to upon the present occasion, however, is the remarkable, and at first sight seemingly mysterious, disappearance of the substance of flints which is everywhere going on around us.

Every London geologist is familiar with formations which are very largely made up of well-rounded flint-pebbles. It is only necessary to mention the Oldhaven or Blackheath pebble-beds, the pebble-beds of the Bagshots, the high-level gravels on the north of London, or, to go farther afield, "the Westleton Shingle" of Professor Prestwich.

It must strike everyone who examines such masses of well-rounded flints that, while the fragments of which they are composed were being gradually reduced by friction and percussion from angular masses to subangular ones, and are finally being worn down to rounded pebbles, considerable quantities of fine dust or sand would be produced; and we might not unfairly expect the matrix in which such pebbles are embedded to consist of a sand made up of comminuted fragments of flint.

Such, however, is not the case. I have again and again examined the sandy matrix of all these deposits, and always with the same result. The fine particles filling the interstices between the rounded flint-pebbles are in all cases more or less waterworn quartz-grains. Particles of flint are either altogether absent or occur in only small and insignificant proportions in the quartz-sand. The same fact seems to have struck Mr. Sorby, for in his very valuable and suggestive address to the Geological Society in 1880 he makes the following remarks:—" At one time I fully expected to find that the sand associated with flint-gravel was itself mainly flint, but I found that, in some cases, at all events, it is chiefly of the normal kind."*

---

* 'Proc. Geol. Assoc.,' Vol. iv, p. 439.

The fact is that, although isolated chips and granules of flint occur in some sands, so far as my own experience goes a "flint-sand" (that is, a sand essentially made up of flint-particles) never occurs. The question, then, which presents itself to us is this: What becomes of the particles of flint which are broken off and ground down during the rolling of the larger fragments of flint? To answer this we must ask what is the real nature of flint; and to this question the microscope affords us the most complete and satisfactory answer.

Silica, of which flint is almost wholly composed, is the oxide of silicon, containing 48 per cent. of silicon and 52 per cent. of oxygen. This oxide of silicon is by far the most abundant binary compound in the earth's crust, of which it forms probably no less than two-thirds of the whole. Silica is a substance which presents in a very striking manner the phenomenon of *Heteromorphism.* Among the different forms of silica there are two which occur everywhere in great abundance, namely, crystallized silica or quartz, with a specific gravity of 2·6, and amorphous, colloid, or glassy silica, known as opal, with a specific gravity of 2·2.† The former of these is of a much more stable character than the latter. While crystallized silica (quartz) is only slowly acted upon by ordinary solvents, the colloid silica (opal) is much more easily affected, and, indeed, passes into solution with comparative ease, especially in the presence of the alkaline carbonates. The colloid opal, however, is an unstable form, and exhibits a constant tendency to pass into the stable crystallized quartz. Chalcedony and other forms of crypto-crystalline silica consist of opal in which crystallites and microlites of quartz are making their appearance in greater or less abundance, the unstable colloid silica passing in this way into the stable crystalline form.

Now flint is a form of crypto-crystalline silica. In all flint we have the colloid opal, through which is scattered in greater or less profusion microscopical particles of crystalline quartz. But there is a wonderful variety in the structure of flints. Some flints exhibit much of their original structure, and are seen to be simply a silicified chalk-mud; others show signs of the crystalline forces having had much greater play, and the rearrangement of the molecules has led to the almost complete obliteration of original structures. Occasionally, flints have their microlites of quartz arranged into those radiated, globular aggregates known as spherulites. From the flints which are simply chalk-mud, in which every particle of the calcic carbonate has been replaced by a particle of colloid silica, and in which only incipient crystallization is exhibited, to the flints in which nearly the whole of the silica has been rearranged by the action of the crystalline forces, there is every possible gradation. In the former, the outlines of the *Foraminifera* and other organisms which have been replaced can be as clearly perceived as in a section of the original chalk; in the latter every trace of organism has been obliterated, and only aggregations of crystalline particles are to be discovered.

---

* 'Quart. Journ. Geol. Soc.,' Vol. xxxvi, p. 56.

† It is not necessary for our present purpose to discuss the rarer allotropic forms of silica known as Tridymite, Asmanite, Vestan, and Christobalite, for concerning the true nature of some of these there is still a certain amount of doubt.

I must now refer to the difference between white and black flint. These two forms constantly occur together, and chemical analysis shows them to be identical in composition—both, in fact, are nearly pure silica. The microscope, however, reveals the cause of their dissimilar appearance. Black flint consists of crystalline or other particles, all the interstices of which are filled up by colloid silica, while in white flints the interstices between the individual particles are not so completely filled up. If we take a piece of black obsidian and grind it to powder, the powder is perfectly white. The reason of this is that we have a reflection of light, not from one surface only, as in the solid piece of obsidian, but from the innumerable surfaces of the particles, as light passes from air into them, and back again into the air, the general effect of these numerous reflections being to produce whiteness. If a piece of blotting-paper which is nearly opaque be dipped in water or oil, it is rendered translucent, because the liquid introduced has a refractive index approaching to that of the fibres of which the paper is made up, and consequently a much smaller proportion of the light is reflected in passing from one medium to the other. On drying, the blotting-paper again becomes opaque, because the highly refracting liquid is replaced by the lowly refracting air, and more reflection takes place from each of the fibres of the paper.

A piece of black flint pounded in a mortar makes a white powder, and a flint when burnt becomes white, not, as is sometimes said, because any organic or other colouring matter is driven off, but because innumerable cracks are produced, and the flint is reduced from a solid and continuous mass to one composed of innumerable minute particles. The white flint in the interior of flint-nodules probably never had its particles fully enveloped in colloid silica. In some cases, indeed, it crumbles to a white powdery mass made up of silicified *Foraminifera*, coccoliths, and other organisms found in chalk, these being often mingled with sponge spicules in greater or less profusion.* The white flint on the outside of flint nodules is usually flint from which part of the colloidal silica has been removed by solution. When water containing carbonic acid and the alkaline carbonates acts upon flint, it is the unstable colloid silica which is first attacked, and the flint becomes white. This whitening of flint by weathering action must be familiar to everyone.

That the silica forming flints was originally dissolved in the waters of the ocean there cannot be any doubt, and that this dissolved silica was derived from the rocks of the earth's crust through the decomposition of alkaline silicates by carbonic or other acids is also certain. We have, unfortunately, no exact determination of the proportion of silica dissolved in sea-water, but the analyses of Forchammer and Dittmar show that proportion to be exceedingly minute. From the observations of the first-mentioned author I think we may conclude that the proportion of silica in sea-water does not exceed, and is probably much less than, 1 part in from 50,000 to 100,000 parts of water!†

---

* It is not necessary for my present purpose to discuss the question if the portions of chalk-mud which becomes silicified to form flint contain an abnormal quantity of siliceous organisms at the outset. Such may very probably be the case, but nothing can be more certain than that chalk-mud, nine-tenths of which consist of calcareous organism, is often converted into flint through the complete replacement of every particle of calcic carbonate by silica.

† Forchammer estimates the proportion of chlorine in sea-water as one part in 50 by weight. He further states that the calcium phosphate and carbonate, the barium and strontium sulphate, the calcium and magnesium borate, the iron salts, and the silica in sea-water altogether form generally less than $\frac{1}{100}$ part of the chlorine! It therefore follows that the whole of the substances mentioned do not exceed $\frac{1}{50} \times \frac{1}{100} = \frac{1}{5000}$ part of the sea-water. What is the proportion of silica to these other ingredients of sea-water has never been determined, but considering how very small is the proportion of silica in the waters of rivers, the estimate of from $\frac{1}{4}$th to $\frac{1}{10}$th of the whole is certainly liberal and probably excessive. In this way we

We know no chemical process by which such minute proportions of silica could be directly precipitated from a state of solution. But there is an agency at present at work in the seas—and, indeed, in all the natural waters of the globe—capable of separating even the minutest portions of silica from solution. I refer to those animals and plants which have the power of secreting a siliceous skeleton.

The organisms which at the present day form siliceous skeletons that on their death accumulate to form siliceous deposits are the *Diatomaceæ*, the *Radiolaria*, and the *Silicispongia*, the first-named of these being plants, and the second and third animals. The relative importance of these three kinds of organisms as manufacturers of siliceous deposits is probably indicated by the order in which I have named them, being in the inverse order of their actual dimensions. The silica is separated by these organisms in the colloid form, and it is sooner or later either redissolved or passes into the more stable crystalline form.

In the absence of any direct evidence to the contrary, I think we may fairly conclude that the organisms which did the work of separating silica from its state of solution in the waters of the ocean in the Cretaceous period were the same as do the work so efficiently at the present day. It is perfectly true that diatoms are unknown in the Chalk, that radiolarians are rare, while the remains of the siliceous sponges are exceedingly abundant. But then it must be remembered that the siliceous frustules of the *Diatomaceæ* are so minute that the chance of their escaping solution is small, and their detection in thin sections of flint, even if preserved, would be almost hopeless. Until recent years radiolarians were almost unknown in the Chalk, and, indeed, in any pre-Tertiary deposits, but the admirable researches of Dr. Rust, of Freiburg, have recently shown that they abound not only in Cretaceous rocks, but in all deposits from the Silurian to recent. Moreover, the spicules of sponges, though so frequently preserved and so easily recognized in rocks of various ages, exist in many cases, in the form of pseudomorphs in calcite, pyrite, or limonite, the original colloid silica having been entirely removed. Even cherts like those so admirably described by Dr. Hinde, which are filled with a network of spicules of which the silica has passed from the unstable colloid state to the stable

---

arrive at the conclusion stated in the text that the proportion of silica in sea-water can scarcely exceed one part in 50,000 or 100,000 parts of water, and is probably much less.

crystalline condition, have their interstices filled with siliceous material which may well have been derived from the solution of diatoms and radiolarians.

That flint, consisting as it does of an intimate admixture of crystalline or colloid siliceous particles, undergoes easy disintegration by atmospheric agencies we have abundant proof. Even the worked flints which have been exposed to this action during the comparatively short periods that have elapsed since Neolithic man flourished in this country have often been converted through great portions of their thickness into the white variety.

Now, minute chips and fragments of flint stand very little chance of escaping solution. Their surface is large in proportion to their mass, and it is to chemical action from their surfaces that they are exposed. At first the solvent carbonated waters, penetrating from without, removes the interstitial colloid silica, leaving the mass in the form of white flint; and in the second place the solvent now able to penetrate around each minute microlite of quartz exercises its full chemical action upon it. This is the reason, as I take it, that fragments of flint and other forms of crypto-crystalline silica are so comparatively rare in sands and sandstones.

But the special point to which I desire to direct attention in this communication is a remarkable property of flint which has much to do with its easy disintegration and solution; I refer to its peculiar conchoidal fracture.

The singular forms found in fractured flints have attracted the attention of many observers, and our President, Mr. Rudler, has formed, at the Museum of Practical Geology at Jermyn Street, a most instructive collection of specimens in illustration of this interesting subject.

The first published discussion of the questions relating to the production of curious forms by fracture in flint was the paper read before this Association by the late Mr. C. B. Rose, F.G.S., of Yarmouth, on the 2nd July, 1860.* He described the formation of the curious flint-cones, and also of the circular cups with nipple-like prominences in their centre, and he proposed to call this phenomenon the "mastoid" fracture of flint. Mr. Rose also clearly pointed out that the taps of a hammer upon a surface of flint produces incipient or concealed fractures, which are by atmospheric agencies, and especially by the action of frost, developed and rendered manifest. In just the same manner granite surfaces, which have been "dressed" by the chisel, are "starred" to a certain depth, and, as is so well shown by the granite monuments from Egypt in the British Museum, are liable to have these starred portions removed by atmospheric weathering. Mr C. B. Rose contributed another paper on the same subject to the British Association at the Norwich Meeting in 1868.*

---

* 'Proc. Geol. Assoc.,' Vol. i, p. 60.

Almost simultaneously with the work of Mr C. B. Rose on this subject, the problem appears to have been attacked by the late Professor Henslow, though, so far as I know, the results obtained by the latter observer were never published. Dr. John Evans states that Henslow discovered how the conical forms of flints could be very easily produced by the use of a hammer with a striking surface in the form of a segment of a sphere. Henslow, like Mr C. B. Rose, seems to have had his attention directed to the subject by the appearances presented by the dressed flints so frequently employed in the East Anglian Churches, where every tap of the hammer of the mason who set the flint in its bed of cement produced a starring, which, by subsequent weathering action, was converted into the well-known appearance which has been variously described as "cup-and-nipple" and "crater-and-cone" structure.

At a later date two other observers seem to have studied the question. Mr. S. J. Mackie, who was the artist that prepared the woodcuts to illustrate the original paper of Mr. C. B. Rose, reproduced those woodcuts with remarks of his own in his 'Geological and Natural History Repertory' in the year 1865.†

In 1868 the subject was taken up by Professor T. McKenny Hughes, who formed a collection in illustration of the fracture of flint, which is still at the Museum of Practical Geology. Unfortunately, Professor Hughes' paper‡ on the subject was never completed, or, at all events, the sheets containing the latter part of his paper seem never to have been issued. He discussed the double cones formed by the fracture of flint and showed that the apical angles of these cones were about 30° and 110° respectively; he also pointed out the different forms of cones produced by vertical and oblique blows upon a surface of flint. Although the mathematical questions involved in the production of these beautiful cones have been referred to by several mathematicians I believe that they have never been fully discussed and resolved.*

---

* 'Brit. Assoc. Rep.,' 1868, Trans. Sect. p. 77.

† 'Geol. and Nat. Hist. Rep.,' Vol. i, p. 208.

‡ *Ibid.*, Vol. ii, p. 126-136.

The bearing of the peculiar fracture of flint on the mode of the formation of flint-implements has, however, been considered by many authors.†

The study of the surfaces of flint-pebbles leads me to the conclusion that their peculiar mode of fracture plays a very important part in bringing about their solution and disappearance. If we pick up an ordinary black flint-pebble, either from the sea-shore or from the Blackheath or similar pebble-beds, and examine it with a lens, we shall find its surface covered by a series of fine curved cracks, often intersecting one another and forming a beautiful pattern. There is a considerable variety in this pattern in different flints, and microscopic examination shows that the size of the pattern formed by the curved lines is in part at least dependent on the texture of the flint. When the flint is composed of uniformly minute crystalline particles enveloped in the colloid matrix, the fracture is remarkably smooth and perfect, and the curved cracks produced on its surface are very fine and regular. When the crystalline particles are larger and more irregularly distributed, the perfection of the conchoidal fracture is greatly impaired, and the pattern of curved cracks upon them is of a less regular kind and is developed on a larger scale.

Now there cannot be the smallest doubt that these systems of curved cracks on the surfaces of flint-pebbles have been produced by the mutual impact of the pebbles upon one another, in just the same way that the curved cracks are formed on dressed flints by the blows of the mason's hammer. In both cases the fracture, which was at first incipient and quite invisible, has been developed by weathering action.

Now, if we examine a number of the flint-pebbles on the sea-shore or in a pit opened in a pebble-gravel we find that a remarkable action has been set up along these lines of cracks. Water containing alkaline carbonates in solution has penetrated along these cracks, and an ever-increasing zone of white flint is being formed along each crack. In this way a white pattern is brought out in strong relief on the black flints. By the aid of microscopic sections, the way in which this change takes place can be satisfactorily traced.

---

* In the Museum of Practical Geology there is a remarkably fine cone produced by the fracture of crown-glass.

† See Falconer, 'Palæont. Mem.,' Vol. ii, p. 605; Evans, 'Ancient Stone Implements of Great Britain' (1872), p. 247; Sir John Lubbock, 'Prehist. Times,' 2nd Ed., p. 79; E. Erdmann, 'Geologiska Föreningens i Stockholm Förhandlinga III.'

The effect of the constant impact of flint-pebbles against one another, therefore, is to produce larger surfaces, which are exposed to the solvent agents. The result of this increase of surface exposed to solvent action may be illustrated by taking a piece of limestone and putting it in dilute acid. As chemical action can take place only where the surface of the mass is in contact with the acid the work of solution is a slow one, and many days may elapse before the lump of limestone finally disappears. But if we take the same piece of limestone and reduce it to fine powder before throwing it into the acid the work of solution may be effected in a few minutes instead of as many days.

In our chemical laboratories it is usual to pound materials in a mortar before attempting to bring them into solution. But in Nature's laboratory the increase of the surface of a mass of flint is effected, not only by actual pulverization, but by the production of these numerous curved cracks along which solvent action can take place. Anyone in a walk along the sea-shore may easily convince himself of the reality of the action I have described by picking up a series of pebbles—beginning with the black ones, in which only the fresh fractures are just visible, up to those in which the whole of the black flint is concealed through the coalescence of the white bands produced on the sides of the cracks.

I have dwelt at some length upon this simple process which is going on everywhere around us, for though so seemingly insignificant, its effects must be of the most wonderful and far-reachin character. While quartz pebbles and grains, which have the same chemical composition, are destroyed mainly by mechanical agencies—and we find in the sands and sandstones of the globe vast accumulations of the quartz detritus—flint, having a peculiar internal structure and mode of fracture, has larger surfaces continually exposed to chemical action, and thus passes into a state of solution.

In the study alike of the making and of the unmaking of flints we find abundant illustrations of the principle which lies at the very foundation of modern geological thought, namely, that small and seemingly insignificant causes, operating through periods of time of vast duration, are capable of bringing about the most stupendous results. A walk along the sea-shore, strewn with flint-pebbles in every stage of removal by the processes we have described, will serve to convince us that in the physical as in the moral world —

> The mills of God grind slowly,
> But they grind exceeding small.

ON THE FORMATION OF ROUNDED FLINT PEBBLES.

BY J. LOGAN LOBLEY, F.G.S.

(*Read Friday, June 3rd*, 1887.)

Rounded flint pebbles form such a well-known and important factor in the constitution of the beds of the South-east of England that geologists generally, and London geologists particularly, must feel interested in the question of the method of their formation. Whether we go to the plateau-like heaths of Kent, or to the commons of Surrey, or, on the north side of the Thames, visit the river-valleys and the round-topped hills of Middlesex, Hertfordshire, and Essex, we are immediately confronted with these symmetrical, ovoid, silent tell-tales of the past. So common and widely dispersed indeed, so conspicuously displayed, and so stratigraphically considerable are they, that the question of the method of the formation of rounded flint pebbles is geologically most important, and ought not to be allowed to drop until it receives a satisfactory answer, and the *modus operandi* is perfectly well known and universally admitted.

The recent interesting and instructive paper by Prof. Judd, 'On the Unmaking of Flints,' will therefore be regarded by Members of this Association as a very welcome reopening of the question; but highly interesting and valuable though the paper undoubtedly is, and as any communication from its author must be, it yet seems to me to ascribe too much of that destruction of the substance of flint which reduces the size and perfects the form of rounded flint pebbles, or the "unmaking" of flints, as it is termed, to the solvent action of water on the flint pebbles of beach shingle.

In support of the solution hypothesis, if I may so call it, the fact is adduced that but a very small amount of flint is to be found in the sands of Tertiary deposits in which the pebbles of old shingle beaches and shingle banks are imbedded; but if the character of sand and that of the particles worn off the smooth surfaces of pebbles by attrition be considered, surprise at not finding these particles in sand will be, I think, removed. Sand, even very fine sand, is composed of grains distinctly separately recognizable by the naked eye, but the particles worn off their surface by flint pebbles rubbing or striking against each other while rolling, must be so extremely minute as to be quite microscopical, and individually entirely unrecognizable in form by the unaided vision. They would, therefore, not form sand at all, nor would they be deposited with it, since the conditions allowing the deposition of the larger and heavier grains constituting sand are necessarily different from those favouring that of an impalpable powder consisting of microscopic particles. The fact, therefore, that little flint detritus is commingled with the sand accompanying old shingle, is what might be expected, even on the supposition of no solution of flint whatever.

The direct argument in favour of the hypothesis is interesting, but, to my mind, by no means conclusive. That the colloid silica or opal, of flint is more soluble in water than the crystalline silica, or quartz, that the extent and rapidity of solution is in proportion to the extent or area of surface exposed to a solvent, and that the minute conchoidal cracks produced by the striking of flint pebbles against each other offer more siliceous surface to the solvent action of water, are all doubtless quite true. The fact, however, that these minute cracks remain minute cracks only slightly developed, instead of widening into miniature fissures or indentations, is evidence that the solvent action of sea-water is marvellously slow and small, and, if one at all, a most insignificant cause of the reduction of sub-angular or large rounded flints to the form and size of Blackheath pebbles, or of the ultimate destruction of such pebbles.

Indeed, the sides of the cracks are not sensibly separated at all, but seem to touch as if there had been no loss of material, whereas did the minute cracks cause solution to take place to the extent required by the solution hypothesis, they would be, it seems to me, in the majority of cases, pittings or indentations rather than cracks, that is, there would be a vacant space consequent upon the loss of solid silica on each side by solution. We ought, in fact, to find flint pebbles generally with their surfaces covered with small crescent-shaped conchoidal pittings or openings penetrating some distance into the pebble; but this is manifestly not so.

I am aware, however, that Lower Tertiary rounded pebbles, removed from their original pebble-bed, and redistributed in river-valley post-Pliocene alluvial gravels, do exhibit in some cases an approximation to the pittings the solution hypothesis requires, but it must be remembered that these have been exposed to the solvent action of water during vast periods of time after the conclusion of the marine conditions which determined their size and shape. Since that epoch in their history they have been subjected to very little attrition, while continuously subject to the action of rain or river water. But even some of the pittings of these which I have examined show signs of having been caused, in part at least, by the sides of the original cracks having been fractured.

It may here be asked also, if solution plays the active part claimed for it, how is it that these Lower Tertiary pebbles remain in existence at all after ages of exposure to water action, sub-aërial or sub-fluvial? They are not only still in existence, however, but, by the retention of the form produced only by rolling, and, above all, by the retention of the beach-formed cracked surface, they have evidently the same size or bulk they had while yet in the original shingle; and, indeed, in many cases, the surface of the pebble is so smooth that even the cracks are still but lines only slightly developed, and are scarcely distinctly visible grooves.

So, too, in the case of the flint implements of pre-historic man, which have been whitened by the removal by solution of colloid silica, the solvent action has been going on through a period of time which, though it may be called comparatively short with reference to geological epochs, is enormously long when compared with the time sufficing for the grinding down of a flint pebble on a tide-washed shore. And, moreover, even after this long-continued solvent action, there is no reduction of size, but only one of density, for the edges have not lost their sharpness, and the implement would be now almost if not quite as serviceable for its originally intended purpose as it was in the hands of its Neolithic or its Palæolithic maker.

To return, however, to the freshly-formed pebbles of our shingle beaches, the microscopic curved grooves at the surface and along the line of the cracks are not sufficiently wide and deep to satisfy the requirements of the solution hypothesis, even were they undoubtedly due to solution and to nothing else; but since it may be fairly contended that they are caused by the razor-edges of the cracks being broken off by the impact of subsequent strikings by other pebbles, even these microscopic grooves cannot be decidedly ascribed to solution. It is, therefore, by no means easy for me to understand how these minute curved cracks can be the cause of any reduction of the lengths of either the longer or the shorter diameters of flint-pebbles, and anything which does not lessen these diameters can scarcely be said, I presume, to be the cause of the reduction and ultimate destruction of these ovoid bodies.

In the year 1856 Mr. Matthew Moggridge, F.G.S., communicated to the British Association some interesting observations he had made with the view of ascertaining the time required to reduce fragments of hard rock to the condition of rounded boulders or pebbles by the action of the sea. Some fragments of rock, angular and irregular both in form and size, were localized in a somewhat sheltered cove, Limeslade Bay, near the Mumbles, on the coast of South Wales, in such a manner that while exposed to only a moderate action of the sea waves, they were confined within a restricted area for a definite maximum length of time, viz., 10 years. None, that is, were exposed longer, while there were continuous additions to the mass of shingle during that time. The general result to be deduced, Mr. Moggridge says, may be thus stated:—"That on a beach not more than usually exposed to the action of the sea ten years sufficed for the formation of 'rolled stones.'"* The term "rolled stones" he had previously explained to mean "completely rounded" stones, and as he found the smaller stones of the whole mass of shingle were generally so rounded, it appears fair to assume that a much less time than ten years had sufficed to effect the rounding of those most easily and consequently most frequently moved by the waves, those stones, in fact, most similar in size to our flint-pebbles. Moreover, it was remarked that although some of these stones were composed of limestone conjoined with insoluble hard iron-stone, all were equally worn, no effect being attributable apparently to solution.

These results will serve to show that the rounding process, in the case of fragments of hard rocks, by no means goes on with the extreme slowness that many suppose, leading to the conclusion, I think, that flints are in like manner worn and rounded far too rapidly for their diminution in size to be ascribed to that solvent power of the sea-water which does not even sensibly widen the cracks in the surface of the pebbles.

---

* British Association Reports," 1856. Transactions of Sections, page 69.

But doubtless it may be asked, has not too much been proved? If angular fragments are worn down into rounded forms by attrition in such a moderate amount of time as has been stated, then they will be entirely worn away and destroyed in no long time, and so shingle could not accumulate or shingle beaches be formed.

To this it may be answered that, unlike solution, attrition only acts during the movement of pebbles against each other, and on pebbles in a position to move or roll, and that such pebbles are only those on the surface, or immediately below the surface, of the shingle beach, and at the same time between, as sailors say, land and water, or just at that constantly varying, constantly advancing and retreating line on the shore on which the waves break. All those at a little distance below the surface, being protected from the action of the waves, are motionless, and so are not exposed to the agency of attrition ; while even those at the surface are only subjected for a short time, and at intervals, to the rolling produced by the waves, which affect different lines of the beach as the tide rises and falls. Solution, on the other hand, is a more or less constantly acting agency, since not merely the pebbles at the surface of the area of a shingle beach that is covered by the sea, but those also that lie underneath, are in contact with the water which penetrates the whole mass of shingle. Not only so, but the dissolving agent penetrates the whole mass of shingle of the portion of the beach above the water-line to a level as high as the level of that line ; and even those piled up above high-water mark are subject to the spray of breakers, to rain, and to the humidity of the atmosphere.

Thus it will be seen that shingle-beaches are protected from destruction by attrition, by the merely occasional or temporary action of this destructive agency, which, however, temporary and intermittent though it be, is sufficiently rapid in its effects, I believe, to quite outstrip the exceedingly slow agency of solution, an agency, I submit, playing a most insignificant part in the destruction of flints.

The fact, however, that in the aggregate there is a large amount of silica in a state of solution in oceanic waters, may suggest to many that as flint detritus is not found forming sands, this marine diffused solution of silica is fed by the dissolving of the substance of flint pebbles forming the shingle of our sea-beaches, and that we must consequently recognize this, and not sedimentary deposits, as the destination of flinty matter.

But, can we not find solid siliceous particles anywhere but in sands? Solid silica removed from flints by mechanical grinding on the sea-shore is to be looked for, it seems obvious to me, not in sands at all, but rather where such minute particles of solid matter can alone have been deposited, namely, in those deposits, consisting of similarly finely divided solid matter, which form argillaceous beds, or in other words sedimentary marine clays. Beds of kaolin immediately resulting from the decomposition of felspar may be exclusively silicate of alumina, but marine sedimentary clays, such as Lias, Oxford, or London Clay, will be found, I think, to contain a proportion of free silica in the form of minute particles; and furthermore these clays will be found to contain particles much larger than those that would be produced by the rubbing of flints against each other.

If a quantity of clean fresh London Clay, taken from its most purely argillaceous zone, be reduced by repeated careful washings until nothing remains that will give the slightest colour or cloudiness to the water, a quantity of fine sand consisting of distinctly visible grains will be found as a residuum at the bottom of the vessel. On examining 1,750 grains troy of such clay when dry, I found a residuum of ten grains weight of clean fine sand, or 1 in 175, or ·057 per cent.; and although this residuum may be chiefly quartzose, and even though it contain no flint whatever, it sufficiently establishes the fact that siliceous particles are deposited with aluminous matter; and if distinctly visible grains are deposited and associated with, and form part of what, speaking generally, would be called argillaceous matter, then it of course follows that smaller particles, such as would be produced by the natural grinding of flints against each other on a sea-beach, may be precipitated with, and be included in, a clay deposit. But these would be so minute that no washing, however careful, could separate them from the aluminous particles with which they would be intermingled, and it would be difficult, I imagine, to detect their flinty, as distinguished from their quartzose, origin and character even by microscopic and polariscopic means.* Many argillaceous beds are furthermore distinctly sandy. Indeed, there is every gradation, ranging from almost pure kaolin to a slightly clayey sand, including our southern extensive sheets of river-valley brick-earths. Thus it must be admitted that there is abundant room in our argillaceous deposits for particles of flint quite outside of, and apart from ordinary sands, where, in my opinion, they ought not to be looked for at all, and consequently their absence there can be no evidence whatever of their non-existence.

It is true indeed that there is a small quantity of flint grains in some sands, but these can scarcely be the result of the grinding action that gives the symmetrical and rounded form and smoot surface, but rather of the fracture of flints by some agency othe than that of mere rubbing, or even of the striking of pebble against each other while rolling on a sea-beach. How often hav e we all seen while sitting on a shingly beach, when the dancin waves have been rolling in and breaking into foam almost at o r feet, pebbles thrown up by the dash of the water and cast to so e distance, when they fall with a distinctly audible concussion on t e mass of shingle. The size of the pebbles so lifted into the air, a d thrown to a distance, depends upon the weight and momentum f the inrushing and breaking wave. It only, therefore, requires a more than average sea to so cast up large pebbles, or what m y almost be called boulders, and these will sometimes be so large a d weighty, and be thrown so high, that they will fall with a breaki g power quite equal to the fracturing of some of the pebbles, espe ally of those which have internal lines of weak cohesion, r incipient cracks, resulting possibly from alternations of temper ture, possibly from the original fall from the Chalk cliff. The does not appear to be much difficulty, therefore, in accounting f the five or ten per cent. of flint grains in some Tertiary sand quite apart from their ascription to the attrition of rolling pebbles but even if solid flint particles resulting from grinding or pu attrition could not be found in any deposits whatever, and, mor over, if even it could be demonstrated, not merely negatively, b t positively, that they are entirely absent, which I believe to be impossible, that fact could not be a proof that such solid particles in abundance never at any time existed. Detached particles of silica, taken off flints in a solid form, are of course subject to whatever solvent power the surrounding and including water may possess, and so, although removed from flint in solid particles, as is here contended, the flint may have been subsequently dissolved, its finely divided condition facilitating solution; and as a matter of fact much is doubtless so dissolved.

---

* It should also be remembered that the total amount of flint detrit must have formed but a very small proportion of the whole quantity of matter contemporaneously deposited in any argillaceous bed, and that the fore it ought to be no matter for wonder (even if they could be detect when present) that flint particles could not be found in any small quantity of clay examined.

I hope I have fairly and sufficiently clearly presented the conclusions to which I take exception, as well as those to which I have myself come, but perhaps they may with advantage be briefly re-stated in conclusion.

To the question—which is the chief agent that effects the reduction of flint pebbles subjected to the action of the waves on a shingle beach,—the paper 'On the unmaking of flints' appears to answer, Solution. On the other hand, I venture to attribute nearly the whole of the reduction and ultimate destruction of flint pebbles to mechanical attrition, by which *solid* silica is removed from their smooth surfaces in exceedingly minute particles, and, its finely divided condition rendering it more amenable to solvent action, much of the colloid, if not of the crystalline portion of the whole is *subsequently* dissolved by the waters of the sea.

ORDINARY MEETING.

Friday, November 4th, 1887.

F. W. Rudler, Esq., F.G.S., Hon. Sec. A.I., President, in the chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association :—Dr. E. J. Ball, F.C.S.; B. H. Brough, F.G.S.; A. E. Gibbs, F.L.S.; J. H. Grant; and H. T. Wharton, M.A.

The President then delivered his address on 'Fifty Years' Progress in British Geology.'

Fifty Years' Progress in British Geology; being an Address on the Opening of the Session 1887-8.

By F. W. Rudler, F.G.S., President.

Introduction.

Bending to that custom of our Association which expects the President to open each Session with an Introductory Address, I purpose soliciting your attention this evening to a survey of the progress of British geology during the last half-century. This subject— as you may well understand—has not been so much selected by me as forced upon me. In a year when most people in this country have been indulging in retrospect, and recalling the past, in order to mark the progress of the nation during the Victorian era, it seemed well to strike in with the humour of the hour, if only to show that the movement of that science which the Members of this Association specially cultivate has not been less rapid or less healthy than the corresponding movement of the cognate sciences. '

It is no unusual thing for an anniversary address to a scientific body to take the shape of a chronicle of the achievements in some particular department of knowledge during the preceding year. In the case of a swift-stepping science like geology it is far from easy to keep pace with its advance, and an annual retrospect becomes nowadays a rather serious affair. To attempt, therefore, to multiply such a task fifty-fold would only be to court disaster. All that we can hope to do within the compass of an hour's discourse is to pass rapidly from branch to branch of our science, touching lightly upon each without dwelling upon any, and taking care that while no department is altogether neglected, none receives an undue share of attention. As, however, we are all likely to know more of the recent development of geology than of its position half-a-century ago, it may be well to give more prominence to the early than to the later chapters of its history.

Geological Philosophy in 1837.

Considering at how late a date geology came to take its place in the circle of the inductive sciences, it is surprising to note what a respectable and even dignified position geology occupied in this

ntry fifty years ago. On the whole the geology of 1837 was
ikingly like the geology of 1887. Speaking broadly, it may be
d that the fundamental principles of the science had been estab-
ed much as we know them at the present day; the methods of
dy had been laid down, the system of stratigraphical classifica-
n had been practically determined, and the nomenclature of the
ence had been organized. And yet, with this general similarity,
re was after all a vast difference, and the more closely we scruti-
e the subject the more strongly does this difference force itself
o notice.

The commencement of the Victorian period could hardly be
led a time of general peace in the geological world. It is true
old fires of the Wernerian and Huttonian controversy, which
burnt so fiercely in the early days of British geology—especi-
north of the Tweed—had died down by 1837, and only
asionally cast forth a fitful flicker—the sure token of approach-
extinction.* The Wernerian geognosy seems at this time to
e been defended only by some of the older men, who, having
lied at Freiberg, were unable to shake themselves free from the
inating influence of their old master. George Bellas Greenough
ho at that time was verging on sixty years of age, and who
y years previously had been mainly instrumental in founding
Geological Society—represented the surviving spirit of Wer-
nism in England, while Prof. Jameson, of Edinburgh—the
der of the old Wernerian Society—remained its half-hearted
pion in the North.

ut though the old battle of the Neptunists and Vulcanists was
tically over, another war-cry had unfortunately arisen to dis-
the atmosphere of British geology. Happily the new conflict,
ing with questions of a less fundamental character than those
h had agitated the earlier controversialists, was carried on
much less severity; but it was still powerful enough to rend
wain the geological world of half-a-century ago. In 1837 the
r of the Geological Society was occupied by the learned his-
an of the Inductive Sciences, and in publishing this very year

---

For the history of British Geology in the early part of this century
Fitton's articles in the 'Edinburgh Review,' Vol. xxix, No. 57, 1817,
58, 1818; Vol. lxix, No. 140, 1839. Conybeare's "Report" in 'Rep.
t. Assoc.,' 1832, p. 365. Also Dr. A. Geikie's 'Life of Sir R. I. Mur-
on' (Cap. vii, "Rise of Geology in Britain"), Vol. i, 1875, p. 96.

the third volume of his 'History,' he devoted the final chapter to a discussion of what he called "The Two Antagonist Doctrines of Geology." When resigning the Presidential Chair in 1839 he recurred to this antagonism, or "fundamental antithesis of opinion," describing the opposing schools of his day under the names of "Catastrophists" and "Uniformitarians."*

In order to realize the situation at this period it is necessary to remember that, although Hutton had pronounced with no uncertain voice in favour of the adequacy of actual causes to produce most of the phenomena studied by geologists, yet this part of his creed failed for nearly half-a-century to attract adherents. Most of the prominent geologists at the period we are studying, while accepting the Huttonian views with regard to such fundamental questions as the origin of granitic and trappean rocks, and the general mode in which the stratified deposits have been formed, nevertheless questioned the geological potency of the existing activities of Nature. In fact, they were often at the pains of nicely discriminating between the causes which are now in action and those which have ceased to act. They failed to realize the significance of breaks in the succession of strata, holding that the change observed in passing from one formation to another, especially if accompanied by a marked change in the organic remains, involved the operation of terrestrial forces differing, if not in kind, at least in a marked and serious degree from those at present in operation. "Such views," said Whewell, writing in 1837, "prevail extensively among geologists up to the present time." †

It was against these catastrophic views that war was so long waged by Sir Charles Lyell. Although continental geologists have generally been favourably inclined towards cataclysmal doctrines, it must not be forgotten that it was a German who has the great merit of having first systematically collected the historical evidence of changes in Nature with the view of casting light upon geological phenomena. This was Von Hoff, of Gotha,‡ who died in the very year we are studying—the year 1837—leaving Lyell in almost undisputed possession of this special field of inquiry. That

---

* 'Proc. Geol. Soc.,' Vol. iii. p. 92.

† 'History of the Inductive Sciences,' by the Rev. William Whewell, 1837, p. 609.

‡ "Geschichte der durch Ueberlieferung nachgewiesenen natürlichen Veränderungen der Erdoberfläche. Ein Versuch von Karl Ernst Adolf von Hoff." Gotha: 1822-1834.

Lyell had already made this subject his own in England is attested by the fact that in 1837 he published the fifth edition of his famous 'Principles'—a work which significantly bore upon its title-page the pregnant sentence of Playfair, "Amid all the revolutions of the globe the economy of Nature has been uniform." The value set at this time upon the 'Principles' is marked not simply by the fact that it had then reached its fifth edition, but by the more significant fact that the Royal Society had stamped the work with its signal approval by the award of a Royal medal. It is true that this award had some relation to Lyell's original researches among the Tertiary formations, but it is evident that a sense of the high value of the 'Principles' was the chief factor in determining the award. The Council of the Royal Society, however, while recognizing the comprehensive scope of Lyell's views and acknowledging his philosophic spirit, distinctly declined to express any opinion on the controverted matter.

Not that any objection could be fairly urged against the fundamental principles of Lyell's philosophy. The common-sense method of making the best of what we positively know in order to aid us in discovering what we do not know had been already recognized by Buffon and other naturalists as a canon of science not to be lightly laid aside.

The main question at issue in the controversy of fifty years ago was whether we should admit the action of moderate forces, such as we are familiar with, operating through long periods of geological time, or the action of violent forces, such as are unfamiliar to us, operating through comparatively short periods. Lyell's teaching and tendency were decidedly inclined towards the former view, and among the early adherents to this mode of reasoning stand the honoured names of Charles Darwin and Poulett Scrope. But the older geologists like Buckland (who was 53 years of age in 1837), Sedgwick (who was 52), and Murchison (who was 45), while acknowledging much excellence in Lyell's method, unmistakably favoured the rapid action of powerful forces, and never became true uniformitarians. Even De la Beche can hardly be claimed as an adherent to Lyell's school.

But the younger men, during the early decades of the last half century, having had their ideas moulded by the 'Principles,' were fascinated by the simplicity of uniformitarianism, and in some cases were led to carry this doctrine beyond the limits which the master himself regarded as legitimate. For it must always be remembered that Lyell—notwithstanding the apparent meaning of certain isolated passages in his writings—allowed more elasticity in the working of the terrestrial machinery than is commonly supposed. In this connection attention may be profitably directed to a letter which he wrote to Whewell in 1837,* and which not only sets forth with much clearness the views which he then held, but offers an insight into the way in which he had reached his conclusions. Brought up under Buckland in the faith of the cataclysmic school, he was converted, in spite of himself, while engaged in writing the first volume of his 'Principles.' From the letter just referred to, it is clear that in 1837 Lyell was certainly not anxious to contend for absolute uniformity in the course of Nature. Conceding that the doctrine of strict uniformitarianism has occasionally been overstrained by some of his followers, let us, nevertheless, admit that it rendered excellent service to geological philosophy in its day, if only as a healthy counterpoise to the earlier paroxysmal school.

Of late years there has been recognized a growth of opinion, I will not say directly towards catastrophism, but towards a less rigid view of the sequence of geological phenomena than strict uniformitarianism would tolerate. The history of British geology from the early part of the present century may be read in the fine series of volumes issued by the Geological Society, and especially in the successive Presidential discourses. Listen to Prof. Duncan's opinion on uniformitarianism as expressed to the Society ten years ago: "Causing," said he, "a monotony in geological reasoning, requiring phenomena at the present time to have their application strained unreasonably, and inferring the lapse of inconceivable time, it has gradually been modified or discredited."†

Again, Prof. Prestwich, addressing the Society after the death of Sir R. I. Murchison in 1872, remarked that in Murchison's early life "opinions prevailed with respect to the former energy of physical forces and the rapidity of geological changes which are not generally held in this country; but it may be a question, while admitting the necessity of modification, whether geological opinion has not in some cases run to an opposite extreme."‡ The same belief finds expression in his Inaugural Lecture at Oxford in 1875—a lecture dealing with the 'Past and Future of Geology;' and in the first volume of his 'Treatise,' published last year, he admits that he had "long been led to conclude that the phenomena of geology, so far from showing uniformity of action in all time, present an increasing series of changes, dependent upon the circumstances of the time."*

---

* 'Life, Letters, and Journals of Sir Charles Lyell, Bart.,' edited by his sister-in-law, Mrs. Lyell, 1881. Vol. ii, p. 2.

† 'Quart. Journ. Geol. Soc.,' Vol. xxxiii, 1877, "Proceedings," p. lxv.

‡ *Ibid.*, Vol. xxviii, 1872, p. xxxiv.

One of the most outspoken arguments of modern days against the uniformitarian school is to be found in the luminous address on 'Geological Reform' delivered to the Society by Professor Huxley in 1869. In that address he expressed his opinion that neither uniformitarianism nor catastrophism is likely to be the system of the future; but that a third school of geological speculation, which he termed "Evolutionism" is "destined to swallow up the other two."†

It may be said that the modern system of geological thought to which Prof. Huxley here refers has been developed by the operation of two causes characteristic of the latter half of the Victorian age. One of these is the endeavour, since the publication of Mr. Darwin's great work, to extend the doctrine of evolution to all physical nature; the other is the great advance in experimental science which has led to the development of an extra-telluric system of chemistry and physics. It has been often said that the great defect of the system of Hutton and Lyell is its want of comprehensiveness; and there is, indeed, no doubt that its tendency is to limit speculation to the history of the earth as revealed by the stratified rocks, and to remain content with an attitude of agnosticism with regard to the early condition of our planet. Hutton's classical 'Theory,' as first published in 1788, concludes with the oft-quoted passage wherein he sums up his inquiry by saying that in the phenomena of geology "we find no vestige of a beginning, no prospect of an end."‡ And Lyell, addressing the Geological Society in 1851, could say that, "after sixty years of renewed inquiry, and after we have greatly enlarged the sphere of our knowledge, the same conclusion seems to me to hold true."§ But of late years this dictum has undergone considerable modification, and most geologists now feel it a legitimate part of their business to search, as far as may be, for that vestige of a beginning which their predecessors were proud to ignore. In modern times the spectroscope has rehabilitated the nebular hypotheses of Kant and Laplace, and has galvanized into fresh life the stiffened body of cosmogony. One of the features of our day is a revival of scientific interest in cosmological hypotheses, and it is hard to see how the cosmologist can ever be a uniformitarian. It is true that geological speculation is scarcely ambitious enough to endeavour to trace the earth's development to its very earliest phases—to that primitive condition, when the elements may have been in a state of dissociation, or that ultra-gaseous condition represented by the hypothetical *protyle* of Mr. Crookes. Leaving, however, such transcendental speculation to the chemist and physicist, the modern geologist may advantageously take up the earth's history at a somewhat later stage, when the nascent globe presented, at least, a consolidated surface. Is it possible to learn anything by direct observation respecting this primitive crust? Has it been altered beyond all hope of recognition, or is it represented—and if so, to what extent—by any of the Archæan rocks? These are questions which in recent years have been frequent subjects of discussion in this country, but they are questions for which the geologist must be content to await an answer in the future.

---

* 'Geology,' by Joseph Prestwich, M.A., F.R.S., Vol. i, 1886, Preface, p. vi.

† 'Quart. Journ. Geol. Soc.,' Vol. xxv, 1869, p. xlvi.

‡ "Theory of the Earth; or, an Investigation of the Laws observable in the Composition, Dissolution, and Restoration of Land upon the Globe," by James Hutton, M.D., 'Trans. Roy. Soc., Edinburgh,' Vol. i, 1788, pp. 209-304.

§ 'Quart. Journ. Geol. Soc.,' Vol. vii, 1851, p. lxxv.

Stratigraphical Geology.

In stratigraphical geology the most marked progress during the last half century has been effected at the opposite poles of the geological scale, partly among the most ancient, partly among the most recent rocks. In 1837 the order of the principal groups of the Secondary and Tertiary Series had been determined with an approximation surprisingly near to accuracy itself. Long before the commencement of the Victorian age the stratified rocks had yielded the secret of their sequence to the patience, the perseverance, and the penetration of William Smith. Mainly by his labours the great Mesozoic series had come to be well understood, and its principal members were labelled with the names to which they still respond. The classification of the Secondary rocks was essentially an English work; that of the Tertiaries was rather—at least in its beginnings—

the work of France.* It was Cuvier and Brongniart who first brought the strata of the Paris Basin into order; but even in 1837 the Tertiaries of our own country had not been neglected. Although Mr. Prestwich—occupied fifty years ago with the Coalbrookdale coal-field—had not then published the first of his remarkable contributions to our knowledge of Tertiary geology, yet Lyell had been busy in field and cabinet, in England and abroad, not simply in marking the sequence of the beds, but in collecting, collating, and classifying their organic remains. The Tertiary geologists of 1837 had just admitted into their vocabulary the Lyellian triplet of "Eocene," "Miocene," and "Pliocene;" Charlesworth was active in describing the Crags of East Anglia, and Bowerbank was engaged in studying the fossil fruits of the Isle of Sheppey.

While the Tertiary and Secondary Formations had thus been fairly dealt with fifty years ago, our knowledge of the older rocks—at least of those below the Carboniferous system—was at that time only just beginning to shape itself into scientific form. These rocks were still commonly known as "Grauwacke," an awkward word imported from the German miners, and stretched from its original lithological meaning until it acquired stratigraphical significance, The Grauwacke group was, in fact, much the same as the "Transition" Series of the Wernerian geognosy. Even in De la Beche's 'Report on Cornwall and Devon,' published in 1839, the term Grauwacke is freely used as a stratigraphical expression, though not without an apology for its uncouthness.† These rocks had been so hardened and squeezed, so folded and faulted, that in many places their relations seemed hopelessly obscure. Nor were the organic remains which they yielded anything like equal in number, in variety. or in state of preservation to those which rewarded the student of the younger rocks. At the beginning of the Victorian era order was gradually being evoked out of this chaotic assemblage of ancient and altered rocks, chiefly by the labours of the two remarkable fellow-workers, Sedgwick and Murchison.

As early as 1822 Sedgwick had tried his hammer upon the old rocks of the Lake District of Cumbria, and at a later period had attacked similar rocks in the mountains of North Wales. After having been exercised for more than a dozen years with the perplexing problems suggested by these rocks, he proposed in 1835 to distinguish the oldest known group by the term *Cambrian*. The next year Murchison suggested for the overlying series of rocks the term *Silurian*, a word so smooth in sound and innocent in meaning that it was straightway adopted by geologists, not only here but on the continent. In 1837 Murchison, having introduced this term, was busy composing his great monograph on the 'Silurian System,' a work which, when given to the world in the course of the following year, marked an epoch in the history of Palæozoic geology.

---

* See Conybeare's remarks. 'Rep. Brit. Assoc.,' Oxford, 1832, p. 371.

† "It has been objected to grauwacke, regarded solely as a word, that it jars harshly on the ear. If this be a sufficient reason to constitute a fatal objection to scientific names, and that all which do not sound harmoniously are to be swept away, the number which in that case must be removed would materially abridge scientific dictionaries." De la Beche's 'Report,' p. 41

While the rocks of Wales were thus under discussion, geological controversy was at the same time waxing warm over the rocks of Devon and Cornwall. Sedgwick and Murchison had visited the West of England in 1836, and had shown by unmistakable evidence in the field that the "Culm rocks" of North Devon, so far from being part of the oldest Grauwacke, as hitherto supposed, actually lay in a trough formed by the slates and limestones of Devon. And while the stratigraphical position of the Culm measures thus proved their superiority to these ancient strata, they were brought by their fossil plants within the range of the Carboniferous system.

Although the age of the Culm measures was settled in this way, doubt still hung over the stratigraphical position of the rocks upon which they reposed, and which, spreading out over a great part of Devon, stretched far away into Cornwall. In De la Beche's 'Report' of 1839 they are still described as Grauwacke. In this Series, however, were included certain limestones rich in fossils; and it was these fossils that in 1837 gave the clue to the stratigraphical position of the rocks in question. This was due to the penetration of Mr. Lonsdale, the gifted and modest worker, who so long held the Curatorship of the Geological Society, and who in examining the Devon fossils, was struck with their mixed and anomalous character. They were not Silurian, neither were they Carboniferous; yet they exhibited characters allying them partly to the one and partly to the other group. Intermediate between the Silurian and Carboniferous systems in the nature of their fossils, the rocks of Devon seemed likewise intermediate in stratigraphical position. It was shown that they lay beneath the Culm in Devon, while in Cornwall similar rocks rested above certain strata containing Silurian fossils. But the rocks elsewhere packed in between these two formations, belonged to the Old Red Sandstone Series, and consequently the Grauwacke and limestones of Devon were supposed to be roughly on the same geological horizon as the Old Red Sandstone. Differing, however, in their lithological character, and especially in the marine character of the fauna which they contained, they seemed to deserve a new name; and in 1839 Sedgwick and Murchison, extending their system of geographical nomenclature, suggested that the rocks of Devon below the Culm measures should be recognized by the term *Devonian*. It was just before this time that the Old Red Sandstone—upon which Hugh Miller was then working in Scotland—was elevated by Murchison to the rank of a distinct geological system.

From this rapid review it will be seen that the early part of the Victorian age was a period of singular activity among the older or so-called Primary rocks. Between 1835 and 1839 the nomenclature of systematic geology had been enriched by the three terms—Cambrian, Silurian, and Devonian. In 1841 another division—either the top of the Palæozoic group or the base of the Mesozoic—was designated by Murchison, in recognition of his Muscovite travels, as *Permian*.

During the last fifty years our knowledge of the several groups of the Palæozoic system has steadily grown: details have been elaborated, gaps filled in, sections described, correlations established, and hosts of new fossils brought to light and studied with exactitude. So far from this progress having been uniformly smooth, many a question has arisen which has been the subject of warm debate; but on an occasion like this we may ask that the hand of charity be allowed to draw a curtain over painful controversies.

Perhaps the most important addition to our knowledge of the stratigraphy of the older rocks of our country during the last fifty years has been the recognition of the Archæan group.

It was in 1854 that Sir W. Logan, while guiding the Geological Survey of Canada, proposed that the pre-Palæozoic rocks which are so largely developed in that country, and were previously known as the "Metamorphic Series," should be distinguished as the "Laurentian" group. Shortly afterwards Sir R. Murchison sought to establish a general parallelism between these Canadian rocks and the ancient gneiss of the Outer Hebrides and the opposite mainland, which he described as the "Hebridean," "Lewesian," or "Fundamental Gneiss."

For our earliest knowledge of the existence of infra-Palæozoic rocks in England we are indebted to the late Dr. Holl, of Worcester, who, having long been familiar with the Canadian gneiss, expressed his opinion in 1863, that the gneissose rocks of the Malvern Hills, instead of being metamorphosed Cambrian strata were really part of an old pre-Cambrian floor. From the Malverns we pass to South Wales, familiar as the battle ground of one of the keenest contests in the recent history of British geology; but as this contest is fresh in every one's recollection it needs no extended discussion in this place. It was in 1871 that Dr. Hicks—whose hammer had so often fallen with telling touch upon the Palæozoic rocks of Pembrokeshire—unfurled the standard of Archaia, at St. David's.* Gradually there rallied round him a group of enthusiastic and fearless geologists who carried the banner into North Wales, and from point to point in England, seeking here and there to wrest a region from the sway of Cambria and Siluria, and ultimately pushing their arms into the Scottish Highlands. The members of the Archæan phalanx are well known to us, for the echoes of the strife have frequently reached this room. Indeed, we may point with pride to the pages of our 'Proceedings,' as containing some of the most important contributions to the great Archæan controversy.

It is, too, a matter of congratulation that it was before this Association that Prof. Lapworth, in July, 1884, read his remarkable paper 'On the Stratigraphy and Metamorphism of the Rocks of the Durness-Eriboll District,'† a paper in which he first announced his original views on the architecture of the Highlands. His conclusions practically agreed with those independently reached by Messrs. Peach and Horne in the course of their official work on the Geological Survey, and published in 'Nature' a few months after the subject had been brought before this Association.‡ These communications opened our eyes to the operation of those Titanic agencies which have not simply folded and faulted the rocks, have crushed and reconstructed them, and even carried vast masses of rock bodily forward, thrusting them along gliding planes for distances of several miles. It seems probable that much of the Scottish Highlands must be regarded as an intricate aggregate of Archæan and Palæozoic rocks, squeezed and sheared, and even kneaded together as clay in the hands of the potter, or flattened out into schists as in a mill. The corrections introduced into the reading of the Highland rocks by this recent work, while rectifying old errors, vastly expand our knowledge of those earth-movements of which our island has been the scene, and must rank among the most notable features in the recent progress of British geology.

---

* "On the ancient Rocks of the St. David's Promontory, South Wales," by Prof. R. Harkness and Henry Hicks, 'Quart. Journ. Geol. Soc.,' Vol. xxvii, 1871, p. 384.

† 'Proc. Geol. Assoc.,' Vol. viii, p. 438.

‡ 'Nature,' Nov. 13, 1884, p. 29.

Before finding another subject of equally keen controversy with the Archæan question, we must pass from these ancient rocks, by a great upward stride, to the Drift. It is true that in so doing we have to step over many questions of high interest relating to the intervening strata, but these questions are of a less exciting character than either the pre-Cambrian or the Glacial controversy. Time would fail to speak of the good work effected in the course of half-a-century among the Mesozoic strata by a crowd of workers, including such men as Phillips, Buckland, Mantell, Morris, Wright, Godwin-Austen, Hudleston, Judd, Blake, Hull and many other of the Geological Surveyors. Nor can we pause at the Tertiary Series to admire the work of Prestwich, Whitaker, Rupert Jones, Starkie Gardner, and others. But rising thence to the so-called Quaternary group (though we might, perhaps, hesitate to separate it from the Tertiary), we encounter a series of irregular yet widely-spread superficial deposits, which during the last fifty years have received year by year growing attention from geologists.

The Glacial Controversy.

Even half a century ago speculation was rife as to the mechanical means which could have brought together the materials of the Northern Drift—those great accumulations of sand and gravel, clay and loam, associated with far-travelled erratic boulders. The term "Diluvium," then commonly applied to such deposits, and still surviving in continental phraseology, reflected the views of the earlier geologists, inasmuch as it suggested the action of a cataclysmic flood, sweeping with impetuosity across the country, tearing up the ground in its course, and driving forward with stupendous force huge masses of solid rock. These extravagant hypotheses of diluvial action gradually gave way before the views of certain geologists of gentler and more moderate mood, who recognized a powerful engine of transport in masses of moving ice.

It is natural that when this frozen vehicle was suggested attention should be directed first to the agency of floating ice. Here was a locomotive agent well known to Arctic travellers, and even familiar to those who in crossing the Atlantic had encountered a fleet of bergs, drifting from the northern waters and laden more or less heavily with a freight of detritus. But a new motor force was introduced when Agassiz, following Charpentier, propounded his views on the movement of terrestrial ice.

Some time before 1837 Agassiz had been busy studying the structure and movement of the ice-streams of his native land, and in that year—exactly 50 years ago—he first sketched his glacial hypothesis before the Helvetic Society. But it was not until his visit to this country in 1840 that he ventured to suggest the former existence of glaciers within the British area. Buckland, with his keen wit, ever ready to suggest a plausible explanation of obscure phenomena, seems to have been the first to see in the smooth rounded hills of Scotland traces of the former passage of land ice over the surface of the country. Travelling in Scotland and in the North of England, in company with Agassiz, after the Glasgow meeting of the British Association in 1840, Buckland's interpretation of such contours was not only abundantly confirmed but widely extended. The young Swiss naturalist, familiar with the effects of glaciers and quick to trace their spoor in every erratic and moraine, came straightway to the conclusion that a great part of Northern Britain, in common with many other parts of the boreal hemisphere, had been not simply the home of vanished glaciers, but the seat of vast ice-sheets which existed at a period in the earth's history that came to be recognized as the "Glacial Epoch." Strongly opposed at first by the "Diluvialists"—under which title were rather unfairly included the advocates of floating ice—it required twenty years before the notion of a glacial period took firm root in geology.

It is impossible here to chronicle the successive stages of the glacial controversy, or even to note the chief contributions to an overwhelming mass of glacial literature. Prof. James Geikie's 'Great Ice Age' may perhaps be singled out as representative of the high glacial school. After half a century of controversy, it is safe to say that the phenomena presented by the drift are sufficiently complicated to allow of the play of a plurality of agencies. The glacier creeping stealthily down the mountain slope; the stately iceberg sailing in Arctic waters; and the sudden flood sweeping over the land, sometimes, perhaps, as a consequence of rapid thaw —each of these agents has played its part, and each has left its mark clear to the eye undimmed by prejudice. One geologist may give too much weight to the action of terrestrial ice, another may assign too large a task to floating ice, and a third may be disposed to magnify the effects of the land flood, or the marine wave, or the pluvial deluge; but each of these advocates is right up to a certain point, and errs only when the reasonable limits of his favourite agent are exceeded.

Concerned as we are at this moment with only a superficial view of the controversy, it is sufficient to remark that the geology of 1837 strikingly differed from the geology of 1887 in that it knew nothing of a glacial period. Considering the large place which this subject has so long occupied in geological thought, it requires some effort of the imagination to picture the state of geology without the glacial theory—as strong an effort, perhaps, as to realize what geology would now be without its Archæan controversy.

Antiquity of Man.

Another subject connected with Pleistocene geology here forces itself upon our attention, and is deserving of special mention, inasmuch as it affects the state of feeling outside geological circles. A patient study of the superficial deposits of the country, coupled with an investigation of the contents of our caverns, has led to one of the most marked revolutions in scientific thought which the last half-century has witnessed. In 1837 no one believed in the geological antiquity of man; in 1887 no one denies it. This remarkable change of attitude towards a question of supreme importance was effected with comparative suddenness some thirty years ago. From the day when Buckland first explored the famous cave in the Kirkdale quarry in 1821, and applied to Yorkshire the lessons which Goldfuss had taught him in Franconia, geologists had felt that every bone-cave in the country was worthy of a patient search, if haply it might contribute something to our knowledge of the Pleistocene fauna. Even before the exploration of the Kirkdale cave certain caverns, or fissures, in the Devonian limestone of Plymouth, quarried for the breakwater as far back as 1816, had yielded bones of extinct species of mammalia. But neither here nor at Kirkdale was there the slightest suggestion that man had been a member of this antique fauna. That suggestion first came from the depths of Kent's Cavern, when MacEnery, in 1825, unearthed a flint implement, said to have been the very first relic of the kind found in a British bone-cavern. The subsequent exploration of this cave by Mr. Godwin-Austen, and later on by a sub-committee of the Torquay Natural History Society, seemed to prove the coexistence of man with some of the Pleistocene mammals. But science, claiming the wholesome right of doubting, refused to nod assent to such evidence, and could only be induced to bend in the face of evidence so clear as to be beyond all possibility of cavil. The proof at last came from a new cavern at Brixham, discovered in 1858, and explored seriously and systematically by a committee of the Royal and Geological Societies. Practically the work of searching this cavern, foot by foot, as also of conducting the famous exploration subsequently undertaken in Kent's cave, fell upon Mr. Pengelly, the mighty Nimrod of the race of cave-hunters. It was reserved for Mr. Pengelly to lay bare the secrets which had been sealed up for ages by a crust of dripstone in the Brixham cave, and thereby to demonstrate the antiquity of man in Devonshire.

Just about the time when these discoveries in the West were causing a flutter in the scientific world, other evidence of a like character was forthcoming from quite a different source. This source was the gravels of some of the valleys in Picardy, where objects of human workmanship and bones of extinct mammalia reposed side by side. It is true that Boucher de Perthes' publications on this subject go back to 1847, and his discoveries to a still earlier date, but the same spirit of scepticism that frowned upon MacEnery in this country, had treated the French antiquary with equal coolness. It was not until Dr. Falconer, fresh from the work at Brixham, visited Abbeville in 1839 that the flint implements, previously treated as unconsidered trifles, became objects of serious scientific attention. The thorough investigation of the subject shortly afterwards by Mr. Prestwich and Mr. John Evans settled the matter once and for all, placing the fact beyond dispute that the worked flints occurred in undisturbed association with the relics of the Pleistocene mammalia.

Attention once drawn to the subject, palæolithic implements were soon found in the older fluviatile deposits of our own land, and discoveries followed in rapid succession at Hoxne, Herne Bay, Bedford, and elsewhere. It is needless, however, to repeat the oft-told tale, familiar to every geologist by the writings of Lyell, Lubbock, Prestwich, Evans, Boyd Dawkins, Pengelly, and others. Suffice it to say that anthropological geology has revealed the existence of an older and a younger set of cave-men, the former perhaps identical with the ancient folk of our oldest river-drifts.

It is not pretended that even the most ancient relic of humanity yet found in Britain dates back beyond the Quaternary period; and hence in this country we are not called upon to pronounce upon the question of "Tertiary man," a question which has so often exercised the minds of continental geologists. But even within this temporal limit there is scope for considerable divergence of opinion touching the earliest appearance of our species. Are we to believe that man never set foot in this country until the glaciers of the Ice Age had melted away? Or, had he dwelt in the land previously to the final glaciation, during some mild episode that may have broken the rigours of the glacial period? Or, finally, had he existed here at a yet earlier date, before the severity of the coming Ice Age had rendered the country uninhabitable? In other words, is man post-glacial, or inter-glacial, or pre-glacial?

Without dwelling upon the discoveries which have been announced from time to time—such as Mr. Skertchley's find of implements beneath the Chalky Boulder-Clay of the Brandon district—I may content myself by reference to the latest researches, those of Dr. Hicks, in the bone-caves of the Vale of Clwyd, already described in our 'Proceedings.' With an enviable kind of intellectual polarity our former President can suddenly swing round from one end of the geological scale to the other, and discuss an anthropological problem with as much originality as he imports into the discussion of an Archæan question. Dr. Hicks has brought forward evidence tending to prove that man existed in North Wales "before the climax of the Ice Age," and he concludes that there seems to be "every reason to suppose that man and the so-called Pleistocene animals arrived in this country in advance of the glacial conditions."* It is true that his conclusions have not yet received unqualified assent in all quarters, but on questions of so delicate and intricate a character it is beyond all things needful to avoid even a suspicion of rashness; and Dr. Hicks will, I am sure, be the first to sympathize with any who feel it a duty to exercise an honest caution in this respect.

Not to linger on the anthropological aspect of geology, I may simply remind you that from these modern researches a new department of science has sprung into being—the science of *prehistoric archæology.* The antiquary of the new school has to study the early relics of humanity not by the light of legend or of documentary evidence, but by the recognized canons of the natural-history method ; treating a stone implement, for instance, exactly as a naturalist would treat a fossil. If it is not necessary that the geologist should concern himself with the details of this new science, it is at least desirable that he should interest himself in its broader features. In fact, as the geologist in studying the succession of the stratified deposits rises to the summit of the series he is confronted with this science of pre-historic archæology. Whether he likes it or not, there it stands before him—Janus-headed, with one face turned towards geology, the other towards history. The existence of such a connecting link shows the futility of the older methods of divorcing the history of the earth, as revealed by geology, from its condition during the so-called human or recent period. Nowadays we rarely speak of "the present order of things"—a phrase so familiar to the geologist of half a century ago, and suggestive of a sharp break between the actual and the geological conditions of our earth. Every step of recent progress has indeed tended to show how vague, how arbitrary, how unphilosophical is the attempt to separate the *Vorwelt* from the *Jetzwelt.*

Geological Cartography.

Closely connected with stratigraphy is the subject of geological cartography. Contrast the maps of 1837 with our maps of to-day, and the difference becomes positively startling. Fifty years ago the only large maps showing the geological structure of England

---

* *Supra*, p. 18.

and Wales were those of William Smith and of Greenough. These were remarkable monuments of sagacity considering the lights of the age in which they were produced; but yet as different from the refined and detailed maps which are the glory of our day as the tools of the Palæolithic man are different from our own.

At the opening of the Victorian period more than twenty years had passed since the enthusiastic mineral surveyor who opened up the way to geological mapping had published his famous 'Delineation of the Strata of England and Wales, with part of Scotland,' the result, as he tells us in the explanatory memoir, of "twenty-four years of intense application." Subsequently there issued from Cary's house in the Strand no fewer than a score of county maps on a larger scale than the general map, but coloured by the same master hand that had first pointed the way to such work.

William Smith's maps were, however, not the only guides that assisted the British geologist of half a century ago. Soon after the appearance of Smith's original map of 1815 another map of England and Wales, richer in detail than its predecessor, representing years of work, by Greenough, aided by several friends, was sent forth under the authority of the Geological Society. This map, published in 1819, was the best that the geologist of 1837 could secure. It was not until 1840 that the second edition appeared, this edition differing from its predecessor chiefly in the treatment of the old rocks of Wales and the Marches, where the hammers of Murchison and Sedgwick had been busy, and in the rocks of Cornwall and Devon, where the Geological Survey had made its first mark.

So far as Scotland was concerned, the older geologists had to content themselves with the map of Dr. John Macculloch, who died in 1836, on the eve of its publication. For Ireland no good map then existed, for it was not until 1846 that Dr. (now Sir) Richard Griffith issued the splendid map upon which he had been engaged, more or less, since 1812; a work which was described by Edward Forbes as "one of the most remarkable geological maps ever produced by a single geologist."

Highly creditable as were such maps as those of Smith and Greenough, Macculloch and Griffith, it was impossible that, representing as they did the efforts of private individuals, they could enter into fair competition with the work which soon afterwards came to be issued by an organized body of scientific labourers, with whom geological mapping formed the profession of their lives. With us, who have usually the advantage of carrying with us on an excursion the Geological Survey sheet of the district to be visited, it requires some effort to realize the position of a geologist fifty years ago, before a single sheet of the official map had been issued. It was about 1836 that De la Beche, already favourably known by work along the western part of our southern coast, began, with the one-inch Ordnance Map in hand, to systematically explore the south-western extremity of England, and to lay down the results of his observations on this comparatively large scale map. Working at first single-handed, and at his own expense, he soon gave such fair promise of public utility as to secure the official recognition of his labours, and in 1832 he received for the first time from the Government a small subsidy towards his expenses. Two years later he was attached to the Ordnance Survey as a geologist under General Colby, and gradually procured assistance from a small band of workers whom he gathered around him. Supported by recommendations from Buckland and Sedgwick, representing Oxford and Cambridge respectively, and by Lyell as President of the Geological Society, he shortly afterwards secured an assured position for the geological branch of the Ordnance Survey.

The first-fruit of this novel organization, which marked an era in British geology, was the appearance in 1839 of maps of Cornwall, Devon, and West Somerset, accompanied by a voluminous Report.

Of these maps it was said by Buckland, speaking from the Chair of the Geological Society in 1840, that they were "more beautiful in their execution, more accurate in their details, and more instructive in the economical and scientific information they give respecting mines, than any maps yet published by any Government in the world."[*] And while such praise was bestowed upon the cartographical work the explanatory memoir was no less warmly welcomed. Indeed, this report, though published nearly half a century ago, is still recognized as one of remarkable merit, and its value is amply attested by the fact that it has been used again and again as a pattern on which similar memoirs have been modelled. During the Long Excursion of this Association last August the Members had an opportunity of visiting the birthplace of the Geological Survey, and of celebrating as nearly as possible its Jubilee.

---

[*] 'Proc. Geol. Soc.,' Vol. iii, p. 221.

The history of the Geological Survey of this country has been so well sketched by my immediate predecessor, Mr. Topley, in his valuable 'Report on National Geological Surveys,' contributed a short time ago to the British Association,* that I am relieved from any necessity for tracing its progress on this occasion. Suffice it to say that in 1845 the English Geological Survey was separated from the Board of Ordnance and placed officially under the Office of Woods and Works; while in the same year the Irish Survey, which had been commenced under Portlock as a branch of the Ordnance Survey, was formally established under De la Beche with Captain (afterwards Sir) Henry James as its Director. In 1854 the Geological Survey was transferred from the Office of Woods to the Department of Science and Art, and in this year the Survey of Scotland was commenced. During the half century of the life of the Survey two of its respected chiefs—De la Beche and Murchison—have passed away in the course of nature, leaving their place to be occupied first by Sir Andrew Ramsay, who, though his hammer has been laid aside, is still with us; and afterwards by Dr. Archibald Geikie, the present occupant of this honoured position.

Geological Literature.

Next in importance to a good map is a good memoir; and it is satisfactory to note that the topographical literature of geology has kept pace with the advance in its cartography. Members of this Association, who have frequently sought guidance in their Excursions, will not be slow to recognize the value of the explanatory memoirs published by the Geological Survey, not one of which, be it remembered, was in existence fifty years ago. Nor should we forget the numerous monographs on localities of geological interest which have appeared as independent publications, like those of Mantell and of Dixon on parts of the south of England, or those of Phillips and of Tate and Blake on areas in the north.

Turning from special descriptions of limited areas, or formations, to general works on British geology, it is well to recall the far-reaching views of Conybeare, who projected in the early days of geology a comprehensive description of the British Isles in four volumes, including two on England and Wales, one on Scotland, and one on Ireland. Unfortunately, only the first instalment of his scheme ever reached completion. This was the famous 'Outlines of the Geology of England and Wales,' by Conybeare and Phillips, published in 1822. Considering the state of stratigraphical geology at that early date the work is one of singular merit, and it is matter of regret that the second volume, in which Conybeare and Sedgwick were to have dealt with the older rocks, never saw the printing office. Conybeare and Phillips's 'Outlines' was the standard treatise to which the student was referred half a century ago. Curiously enough more than fifty years passed from the date of its issue before the publication of another work on similar lines. It was not until 1876 that Mr. Horace B. Woodward published his valuable volume on the 'Geology of England and Wales,' a work of sufficient merit to evoke a word of warm commendation from the Presidential chair of the Geological Society, when Prof. Bonney placed the balance of the Wollaston fund in its author's hands. During the present year a new and greatly extended edition of this useful work has been published. The appearance of this treatise, trustworthy in its information, and rendered doubly serviceable in its new form by its copious references to original authorities, cannot be without a stimulating influence upon the progress of British geology. Associating Mr. Woodward's volume with the works on the geology of Ireland by Mr. Kinahan and by Prof. Hull, and that on Scotland by Dr. A. Geikie, the student is now in possession of a range of volumes going far towards the realization of Conybeare's scheme of a complete treatise on the geology of the British Isles.

---

* 'Report of the 54th Meeting, at Montreal, in 1884,' pp. 221-237.

As Members of this Association, visiting from time to time various parts of Southern Britain, we learn to value, at its due worth, the assistance of a geological guide-book arranged topographically rather than stratigraphically. Such a work we fortunately possess in the 'Outlines of the Geology of the Counties of England,' a convenient and excellent work brought out in 1881 by Mr. W. Jerome Harrison, F.G.S.

---

* 'The Geology of England and Wales, with Notes on the Physical Features of the Country,' by Horace B. Woodward, F.G.S., 2nd Ed. (George Phillip and Son), 1887.

The student of the present day rejoices in a wealth of geological text-books, such as his predecessors of a former generation could never have anticipated. He may turn with confidence to the recent works of Geikie, Prestwich, Green, Jukes-Brown, Portlock and Tate, Page and Lapworth, not to mention a crowd of minor manuals. But to enlarge upon the general literature of our popular science is beyond our present purpose.

Geology and Engineering.

It would be ungrateful on the part of a geologist, who is called upon to review the modern progress of his science, if he neglected to acknowledge the debt which descriptive geology owes to the engineer. The rise and development of our railway system practically coincide with the Victorian age. Let us never forget how largely the operations of the railway-engineer have contributed to our knowledge of the stratigraphical relations of the British rocks. In all directions he has intersected the country with trenches, or drilled it with tunnels, which have laid bare the structure of the island in a manner previously unknown and otherwise unattainable.

Nor should our subsidiary obligations to the railway be passed over in silence. As a body of students, learning perhaps more from our field Excursions than from our indoor meetings, we are constantly reminded of our indebtedness to railway engineers, if not for formally conducting our Excursions, at least for permission to visit their sections. Neither must we forget that without the rapid and cheap means of locomotion offered by railways our Excursion arrangements would be brought practically to a standstill. It is instructive to contrast the facilities for travelling offered by the liberal arrangements of the railway companies at the present day with the difficulties, the time, and the money which had to be expended for a like purpose fifty years ago. In fact, at the beginning of the Victorian period no one could afford to cultivate a taste for geology unless he were a man of means and leisure.

Another branch of engineering to which the modern geologist stands deep in debt is that of well-boring. In 1837 the classical Artesian well at Grenelle, in the south-west of Paris—the first enterprise of this character—was in the midst of execution. It had been commenced four years previously; it was completed four years later. In our country we have followed, within the last thirty years or so, with deep borings at Harwich, Kentish Town, Tottenham Court Road, Ware, Turnford, Richmond, Chatham, Swindon, and elsewhere. These undertakings have been fraught with rich geological interest. Indeed, many an obscure question, which we could hardly hope otherwise to solve, has found a ready response at the end of the diamond-drill; and geologists like Prestwich, Godwin-Austen, Whitaker, and Judd have read with sagacity the story of the strata as interpreted by the Artesian auger.

One notable incident, which ought not to be omitted in any chronicle of recent geological work, is the fact that a deep experimental boring, solely in the interest of science, was undertaken at Netherfield, near Battle, in Sussex, at the instance of Mr. Henry Willett, in commemoration of the visit of the British Association to Brighton, in 1872. The Sub-Wealden boring, managed by a Committee, with Mr. Willett and Mr. Topley representing the Executive, opened our eyes to some unexpected features in the eastward extension of the Kimeridge Series, though it failed to touch the Palæozoic floor. At present the Sub-Wealden exploration stands out as the first and only undertaking of its kind. It may be long before anyone will imitate Mr. Willett's enterprise by embarking on another costly undertaking for purely scientific ends. Nor does it seem likely that we can engage the interest of any special society in such a work. It seems to me, therefore, a matter of some regret that among the many ways in which money has been spent this year in celebration of the Jubilee there should not have been included a memorial in the form of a Jubilee Boring—a deep boring in some well-chosen spot (or, better still, a series of borings) that would ever have been remembered in the annals of British geology, and might have yielded a substantial contribution to our knowledge of the land we live in.

Deep-sea Exploration.

From these deep borings of the earth we pass naturally to the deep probing of the waters. Thirty years have slipped away since the soundings of the North Atlantic, for the purpose of finding a suitable resting place for the first Anglo-American cable, revealed the geological importance of deep-sea exploration. The light which these soundings shed upon the origin of chalk—though not unclouded by a considerable tinge of error—was alone sufficient to show the geologist that great things might be expected from a closer scrutiny of the oceanic floor; and consequently geologists have zealously co-operated with biologists in all efforts to promote deep-sea exploration. The waters of the Ægean had been dredged as far back as 1841 by Edward Forbes ; but a far ampler field was opened up by the labours of Dr. Carpenter, Sir Wyville Thomson, and Dr. Gwyn Jefferys—all three, alas! now passed over to the majority. It was mainly to their instrumentality that we owe the voyages of the *Lightning*, the *Porcupine*, and the *Valorous*, and the crowning work of the *Challenger*. As the subject of deep-sea investigation was treated with characteristic ability by Mr. Hudleston, in his Presidential Address some years ago,* I am freed from the necessity of pursuing the subject into its details.

While deep-sea exploration has been the main object of our recent scientific voyages, geologists should not forget their indebtedness to many of the other surveying expeditions which have been fitted out from time to time by the British Government. In 1837 the *Beagle* had just returned from its long voyage, memorable for having carried Mr. Darwin round the world. Among other scientific missions of direct or indirect interest to geology may be mentioned the voyage of the *Rattlesnake*, with Prof. Huxley on board ; the voyage of the *Fly*, with Mr. Beete Jukes as naturalist ; and the great Antarctic expedition that carried Sir Joseph Hooker. Of all the expeditions, however, that of the *Challenger* stands out as the most conspicuous, its voyage occupying a worthy place among the scientific achievements of the Victorian age. It carried to the uttermost parts of the earth a staff of accomplished naturalists, who, returning with their good ship laden with a rich cargo of purely scientific results, realized, to a great extent, the Baconian idea of "Merchants of Light" in the 'New Atlantis.'

Petrology.

Having dealt, so far as time would permit, with the progress of speculative or theoretical geology and of stratigraphy, with the subordinate branch of cartography, it remains to deal with that important part of geology which comes into direct touch with the natural-history sciences. This division naturally drops into two sections—Petrology and Palæontology—according as it is related to the inorganic or to the organic departments of natural history. It seems convenient to commence with the former.

---

* 'Proc. Geol. Assoc.,' Vol. vii, 1882, p. 245.

One of the first things that strikes the observer in looking back at the state of geology in this country fifty years ago is the humiliating position then taken by petrology and the kindred science of mineralogy. This becomes all the more striking when we recall the marked attention which these sciences had received while the founders of British geology were busily laying down the basis of our science in the beginning of this century. It was a prime excellence of the geognostic school of Werner that it required its disciples to distinguish one mineral from another with all the exactitude which the science of that day could command. Wherever the teaching of the Freiberg professor had been carried by his pupils, there a knowledge of minerals was sure to be cultivated and encouraged. But with the decline of Wernerianism the study of minerals gradually lost its hold upon our geologists, and even the taste for forming mineralogical collections ceased to be fashionable. During the first half of this century the patriarchs of the science passed away one after another, and the younger men who stepped into their places cared less for the inorganic than for the organic treasures of the rocks. It is true that in Scotland, and even in Ireland, the study of minerals was still popular, but in England a taste for mineralogy gave place to the love of palæontology. "Exact petrology," says Prof. Bonney, "at any rate in England, found few followers after the death of De la Beche."*

In order to mark the decline of such studies turn to the publications of the Geological Society. The first series of its 'Transactions' consists of five volumes, published between 1811 and 1821. These volumes contain 119 papers, of which no fewer than 50 relate to minerals and rocks; in other words, 42 per cent. of the published communications to the Society were devoted to these objects. But in the first five volumes of the 'Quarterly Journal' of the same Society, published between 1845 and 1849, we find that, instead of 42 per cent., but little more than 9 per cent. of the papers were dedicated to petrology and mineralogy.

While an apathy towards such studies marked the early half of the Victorian age, the latter years of this period have witnessed a remarkable revival in these studies. Compare the first five volumes of the 'Quarterly Journal' with the last five volumes—the work of the Society between 1845 and 1849 with its work between 1882 and 1886—and it will be found that the proportion is doubled; the 9 per cent. of the former period having risen to 18 per cent. during the latter. But even this increase by no means adequately represents the revival of the study of rocks, since the Mineralogical Society, which came into existence only in 1876, has received a number of communications which in former days would certainly have been sent to the Geological Society.

---

* 'Quart. Journ. Geol. Soc.,' Vol. xli, 1885, p. 59.

It is not too much to say that the remarkable modern revival in petrology dates from the introduction of the method of examining delicate slices of rocks and minerals by transmitted light under the microscope. For this method, as for so many other original suggestions, geology owes its thanks to Dr. H. C. Sorby—an observer who, while dealing from time to time with a great diversity of scientific problems, has not merely adorned everything he has touched, but has substantially enriched it with the gifts of a rare genius. In his classical paper 'On the Microscopical Structure of Crystals indicating the Origin of Minerals and Rocks,' communicated to the Geological Society thirty years ago, may be found those germs which, first falling on the fruitful soil of scientific Germany, have developed into the new petrography, bearing rich fruit in all parts of the world.

Sorby's method, taken up in Germany with a perseverance characteristically Teutonic—especially by such men as Vogelsang, Zirkel, and Rosenbusch—has become expanded into a novel branch of science which is daily attracting new workers. Indeed, the professor who stands forth as the most prominent figure in the development of this knowledge on the continent has made his little laboratory at Heidelberg a centre of dispersion, whence petrological teaching of the highest order is distributed to all nationalities.

Fortunately there have not been wanting in this country those who fully recognize the need of studying our British rocks by aid of these latest developments of optical mineralogy; and the last ten or twelve years have witnessed much honest work accomplished in this direction by a corps of some dozen ardent observers, including Messrs. Allport, Bonney, Cole, Collins, Davies, Forbes, Geikie, Hatch, Judd, Macmahon, Phillips, Rutley, Teall, and Ward.

In the course of our last session we enjoyed the advantage of a discourse from Mr. Teall, in which the new petrography was applied to unravel the histology and pathology of certain rocks, that is to say, their minute structure and the changes they have suffered. These rocks were taken from the opposite extremities of Britain—from the south of Cornubia and from the north of Caledonia—and the paper itself deserves special recognition, inasmuch as it brought prominently before us the modern view of the origin of certain crystalline schists by the operation of pressure upon igneous rocks. The progress of our knowledge of metamorphism has been admirably sketched by Prof. Bonney in his Presidential Address to the Geological Society in 1886.* Quite recently there has sprung up an increased belief in the potency of mechanical pressure as a prime factor in producing widespread metamorphism. Such views have been ably worked out on the continent by Lossen and Lehmann, by Heim and Lory, while in this country they have found able exponents in Mr. Teall and Prof. Lapworth. By the effects of pressure the deep-seated rocks have suffered plastic deformation with accompanying molecular changes, resulting in the alteration of pre-existing minerals and the development of new ones. It is not too much to say that the explanation of regional metamorphism as largely due to mechanical pressure, is one of the most prominent features in the recent development of petrology.

Before dismissing this subject I may, perhaps, be permitted to congratulate British geologists on the prospect of soon possessing a treatise on the petrography of our native rocks, from the masterly pen of Mr. Teall. The early part of this work has already appeared in serial form, and is therefore familiar to those interested in the subject. Looking at the beauty and fidelity of the plates, not less than to the lucidity and thoroughness of the accompanying text, there can be little hesitation in predicting that the work, when completed, is destined to stimulate the study of British rocks, and to dispel the notion too often entertained by young students that a rock must needs lack interest if it lacks fossils.

Palæozoology.

Turning to palæontology, and glancing back for fifty years, a brighter picture meets our eye than that presented by the petrology of 1837. The geological naturalist was then abroad. Most of the younger men were at that time throwing themselves into the study of organic remains with all the ardour that a new branch of science is apt to enkindle. The popularity of palæontology about this time may be largely attributed to the influence of Buckland and of Mantell. During the preceding year (1836) Buckland had published his 'Bridgewater Treatise'—a work that immediately found its way to general favour, not less by the elegance of its diction than by the ingenuity of its arguments. Many readers who took no interest in stratigraphical geology were nevertheless charmed with his description of the eye of a trilobite or the ink-sac of a belemnite. But it was perhaps the restoration of the larger vertebrata that led the public to regard the new-born science of palæontology with a mixture of curiosity, admiration, and amazement.

---

* 'Quart. Journ. Geol. Soc.,' Vol. xlii, 1886, p. 55.

Cuvier—the modern Aristotle, who has been regarded as the founder of palæontology—had passed from his labours a few years previously; but the principles of comparative osteology which he had established were taken up and applied with zeal in our own country by Professor (now Sir Richard) Owen, who, after half a century of subsequent activity, is still amongst us, full of years and honours. The beginning of the Victorian era found Mr. Owen, then 33 years of age, busily engaged in studying the fossils brought home by Mr. Darwin in the memorable voyage of the *Beagle*—a work for which Owen, in the following year, received the Wollaston Medal. This medal, about the period we are discussing, was usually awarded for work more or less of a palæontological nature. In 1837 a double medal was adjudged to Cautley and Falconer for their discovery of the Siwalik fauna; in 1836 the medal had gone to Agassiz for his researches on fossil fishes; and the preceding year it had been given to Mantell for his Wealden work, especially in relation to the Deinosaurs.

While Owen was astonishing the world by his restoration of the extinct animals of South America, including forms of gigantic growth, Ehrenberg, in Berlin, was engaged upon palæontological researches of a microscopic character. Familiar as the fact is to us at the present day, it is difficult to realize the effect, not in scientific circles only, but among the public at large, when Ehrenberg, just before the Victorian era, announced his discovery that masses of rock of enormous magnitude were made up of the exuviæ of multitudes of microscopic organisms. It came upon the world like a revelation, and its effect was soon felt in our own country. While the great Ehrenberg—whom Humboldt, with pardonable patriotism, ranked even higher than Cuvier—was thus working in Berlin, the quiet, painstaking, and acute Lonsdale was occupied in London with the investigation of the minute organisms in Chalk. In the course of the last half century micro-palæontology has grown steadily in scientific favour, and we have had a succession of admirable workers in its various departments, producing results of the highest order, and including such men as Dr. Carpenter, Prof. Rupert Jones, Mr. Brady, Dr. Wallich, and Dr. Hinde.

In referring to the palæontology of half a century ago, it would be unpardonable to omit mention of the place which Agassiz then occupied. Although at that time only thirty years of age, he had already won his spurs as a student of fossil fishes, and had had the satisfaction of being a Wollaston Medallist at the early age of eight-and-twenty. It was in 1840 that he paid his memorable visit to this country for the purpose of studying our fossil fishes in the Old Red Sandstone; and it was then that he proposed a classification which, although it has broken down with the test of time, seemed to commend itself to geologists by its extreme simplicity, and even now survives in our recognition of the order *Ganoidei*.

The mention of the Old Red Sandstone fishes recalls the memory of Hugh Miller. Fifty years ago this remarkable man was patiently working in obscurity among his native rocks on t shores of the Moray Frith, and it was not until the meeting of British Association in Glasgow in 1840 that he was led forth the full blaze of the scientific world. As a picturesque exponent of geology he took his place by the side of such men as Buckland and Mantell, and like them was the means of attracting many young intellect into close communion with the rocks.

Soon after the commencement of the period which we are now discussing, the literature of geology began to be enriched by the writings of one who, while he occupied the position of a master in palæontology, was eminent in almost every other branch of our science. The name of John Morris can never be mentioned in this Association without reviving the most affectionate memories; but mindful of the fact that Mr. Topley has laid before us a feeling memoir printed in our 'Proceedings,'* I need only now remind you how largely Prof. Morris contributed to the progress of geology, and notably to palæontology, throughout the greater part of the Victorian period. Fifty years back Morris was actively collecting materials for his 'Catalogue of British Fossils,' a work first issued in a complete form in 1845. Published at a time when the chief palæontological works of reference in this country were Parkinson's 'Organic Remains' and Sowerby's 'Mineral Conchology,' then unfinished, (the latter a remarkable work, whose beautiful plates are of perennial worth) Morris's 'Catalogue' may be fairly reckoned one of the most valuable contributions which it has ever been the fortune of British palæontology to receive.

---

* Vol. ix, No. 6, May, 1886, p. 386.

Few, I think, will be disposed to differ from me if I venture to say that the central feature in the palæontological progress of the Victorian age in this country has been the work of the Palæontographical Society.* Established ten years after the commencement of this period, it can boast of having produced a noble series of two-score volumes in the course of as many years. Embodying some of the best work of the best workers in their several departments, it stands as a whole unsurpassed, whether we regard the scientific value of the text, or the artistic merit of the plates. It is a pleasure to recall the fact that the success of the Society's work is largely due to the energy and sagacity of one of our former Presidents—the Rev. Professor Wiltshire.

As an illustration of the valuable work accomplished through the medium of this Society, I may point to the opening monograph in the current volume—'A Monograph on the Morphology and Histology of *Stigmaria Ficoides*,' contributed by the veteran botanist, Prof. W. C. Williamson, of Manchester. And this naturally leads me to glance at the progress of palæophytology during the last half-century.

Palæobotany.

It was in 1837 that Sir John (then Mr.) Hawkshaw discovered a remarkable fossil tree erect in a railway section which he was then cutting on the Manchester and Bolton line. His discovery, soon afterwards, of a forest of similar trees magnified the debt which the geological botanist already owed to railway enterprise. These discoveries, taken in conjunction with Mr. Binney's observations elsewhere, showed conclusively that the trunk of the *Sigillaria* passed uninterruptedly down to the stigmarian base, which, spreading and forking in the nether "seat-stone," clearly represented the roots of the sigillarian tree. Not only did this discovery demonstrate the relationship between two bodies previously regarded as generically distinct, but it furnished a powerful argument against the the drift-theory of coal-formation popular among geologists half-a-century ago. Against this view another powerful blow was soon afterwards levelled, when Logan sagaciously interpreted the fact that in the South Wales coal-field seam after seam of coal—to the number in some cases of a hundred—was invariably supported by an underclay penetrated by stigmarian rootlets, and representing the ancient soil upon which the coal-forming plants once flourished. The observations of Hawkshaw, Binney, and Logan thus seemed to settle the great controversy respecting the general origin of coal, so far, at least, as related to the more important seams, leaving to those who favoured its derivation from drifted vegetation only certain smaller patches of coal, of exceptional occurrence, and of little or no economic value.

---

* For an account of its origin, see Dr. Woodward's remarks, *supra*, p. 128.

This digression respecting the origin of coal—a question properly pertaining to physical geology—was suggested by a reference to the fact that the true nature of Stigmaria was first detected exactly fifty years ago. The same year (1837) was noticeable for the fact that Lindley and Hutton then published the last volume of their valuable treatise, 'The Fossil Flora of Great Britain.' Since that time the most brilliant advances in the study of Palæozoic plants in this country have been due to Prof. Williamson, who stands forth as the most commanding figure in the development of palæobotany in this country during the Victorian period. Since 1871 he has contributed to the 'Philosophical Transactions' a series of classical papers on Coal-Measure Plants embodying his microscopic labours, and forming, to borrow the words of Prof. Miall, a "splendid collection of researches entitled to the highest honours in a field where many have attained to excellence."* As a fellow-worker with Prof. Williamson, whose record of scientific labour is equally honourable and extensive, must be mentioned Sir J. William Dawson, who, though working in the West, has often contributed his results to the journals of this country, thus forming a connecting-link between Trans-atlantic and Cis-atlantic science. Neither must the work of Sir Joseph Hooker be omitted, though he long ago quitted the dry paths of fossil botany for fresher fields.

---

* 'Coal, its History and Uses,' by Profs. Green, Miall, Thorpe, Rücker, and Marshall. London, 1878, p. 75.

Nor is any Member of this Association likely to forget the labours of their former President, Mr. Carruthers, whose wealth of knowledge has so often been freely expended for our benefit, and who some ten years ago addressed to us from the Presidential chair two masterly discourses on his special science. Among recent contributions to Palæozoic botany I should be culpable were I to omit reference to Mr. Kidston's 'Catalogue of Palæozoic Plants' in the British Museum.

Turning to the vegetable relics which occur in the younger strata, especially in the Tertiary group, it is at once a pleasure and a duty to accord the foremost place to Mr. Starkie Gardner's researches—researches which in recent years have greatly advanced our knowledge of the Eocene flora, especially by correcting wide-spread errors, and which have frequently been laid before this Association and recorded in our 'Proceedings.'

General Palæontology.

Looking broadly at the palæontological work—both zoological and botanical—of the present day, it may perhaps be said that its most notable feature is the extreme specialization which the advanced state of the biological sciences rigidly demands. With the unprecedented development of every branch of natural history within recent years, no man, however rich his intellectual endowments, can hope to master a widely-extended field with any advantage to himself or to science. In palæontology this is pre-eminently the case, and the men of most incisive mark are the men who, instead of dissipating their intellectual light over an extensive field, are content to focus it upon a limited group of fossils. Witness, for instance, the brilliancy of Davidson's researches focussed upon the brachiopods.

And thus it comes about that we see at the present time admirable work in course of accomplishment by specialists in almost every department. We may watch Dr. Hinde and Prof. Sollas working at sponges; Prof. Lapworth and Mr. Hopkinson occupied with their graptolites; Prof. Rupert Jones, Mr. Brady, Mr. Millett, and Mr. Sherborn bringing the microscope to bear upon the *Foraminifera;* Prof. Duncan, Prof. Nicholson, Mr. Tomes, and Mr. Thomson busy upon corals; Dr. Herbert Carpenter and Mr. Etheridge, Jun., engaged with their crinoids and blastoids; Mr. Vines and Mr. Waters carrying on Prof. Busk's work upon the

Polyzoa; or Miss Crane and Mr. J. F. Walker following up Davidson's researches on brachiopods. If we turn to the *Mollusca* proper we find work of the highest character carried on by such men as Mr. Hudleston, Mr. Etheridge, and Prof. Blake. Among the *Crustacea* and other arthropods Dr. Henry Woodward remains as active as ever, while good work is also being accomplished by Mr. Peach. Prof. Rupert Jones, it need hardly be added, is always at home with the *Entomostraca.* In vertebrate palæontology we observe quite a large group of naturalists at work on the fishes—Dr. Traquair, Prof. Young, Mr. Wm. Davies, Prof. Miall, Mr. E. T. Newton, Mr. J. W. Davis, and Mr. Smith Woodward. The labyrinthodonts are well cared for by Prof. Miall, while the saurians are safe in the keeping of Mr. Hulke, Prof. Huxley, Prof. Seeley, and Mr. Lydekker. Finally, the mammals are objects of solicitude on the part of Prof. Boyd Dawkins, Mr. Lydekker, and Mr. E. T. Newton. As to Man, we may commit his remains with confidence to the care of the anthropologists.

The Work of Mr. Darwin.

It would be wrong to conclude this record of palæontological progress—brief as it must be—without a passing reference to the remarkable change of opinion respecting the origin of species which has marked the latter half of the Victorian age. The change of attitude towards this question is strikingly seen on comparing the ninth and tenth editions of Lyell's 'Principles'—the former published in 1853, the latter in 1867. Between these dates Mr. Darwin had given to the world his epoch-making volume. But although the 'Origin of Species' did not appear until 1859, the views therein enunciated were the result of gradual growth in the author's mind since his return from the voyage of the *Beagle.* Prof. A. Newton, in lately addressing the British Association, has pointed out that the earliest record of Darwin's views on the mutability of species goes back to 1837, so that the present year represents the Jubilee of what I may call the dawn of Darwinism.*

But whether a species be a fixed and unalterable entity, or merely the transient representative of a series of progressive existences, it is equally convenient, and even necessary to describe newly-discovered forms; though it may be devoutly hoped, in the interest of geology, that the modern evolutionary teaching will tend to discourage the multiplication of new species.

---

* At the time this address was delivered (Nov, 1887) the 'Life and Letters' had not been published.

The mention of Mr. Darwin's views recalls the fact that in 1837 he read before the Geological Society two papers relating to subjects with which his name will always be associated. The first of these papers, read on May 31, was 'On Certain Areas of Elevation and Subsidence in the Pacific and Indian Oceans, as deduced from the Study of Coral Formations.' Here he unfolded for the first time his famous hypothesis which brought the several forms of reef and island into relationship,—an hypothesis characterized by equal ingenuity and simplicity. In the face of objections which in recent years have been urged against this view it is only fair to remark that the veteran Prof. J. D. Dana—an authority of the first rank on such a subject—after carefully weighing the objections, believes that the main features of the original theory remain unshaken.

The second paper communicated to the Geological Society by Darwin in 1837 was brought forward on November 1st, exactly fifty years ago. This memoir, 'On the Formation of Mould,' opened our eyes to the part which worms played in the formation of so-called vegetable mould; and the observations there recorded, amplified by long-continued subsequent investigations, were expanded into that well-known treatise—the last that was delivered from the pen of the great naturalist of the nineteenth century.

Geological Museums.

If I were not reminded that the patience of even so indulgent a body as this Association has a limit, I should be tempted to enlarge on the increased facilities for geological study which we enjoy at the present day in our Museums, Colleges, and Societies. As it is, I must confine myself within the narrowest bounds, and deal solely with the metropolitan institutions. First and foremost is the noble geological collection in the British Museum. It would be interesting to contrast the present condition of that collection, under the able guardianship of Prof. Flower, Dr. Woodward, and Mr. Etheridge, with its condition under Mr. König in 1837. At that time it formed part of what Cobbett a few years previously had described in the House of Commons as "the old curiosity-shop in Great Russell Street."* At present it is located in the noblest building which Britain ever consecrated to the purposes of pure science. In this palatial museum the fullest opportunities for study are afforded to the poorest visitor, while the collections are interpreted for the benefit of the public by a profusion of descriptive labels, illustrative sketches, and admirable guide books. In 1850 a writer could say: "It is not creditable that in a National Collection like the British Museum so little is done to facilitate the acquisition of knowledge by the unlearned visitors."† How different is all this at the present day! Can any means be better devised for conveying scientific knowledge to the public than the admirable and cheap Guides to the Geological Galleries by Dr. Woodward, and to the Mineral Department by Mr. Fletcher? The frequent visits of the Association to the British Museum have enabled us to realize the high educational value of this institution, and our visit last spring to the new Historical Gallery, to inspect the type collections under Dr. Woodward's guidance, will be fresh in the memory of all who availed themselves of the privilege.

Another metropolitan collection which offers great facilities to the student of our science is that in the Museum of Practical Geology—an institution of much younger growth than the British Museum. Its existence, in fact, curiously coincides with the Victorian period, for it was in February, 1837, that Lord Duncannon, representing the Woods and Forests, commissioned Sir H. T. De la Beche to form a museum. This was at first of an unambitious character, being located in small apartments in Craig's Court, and known as the Museum of Economic Geology.

In 1851 the collections were removed to the more worthy building which Mr. Pennethorne had erected in Jermyn Street, an event sufficiently notable to find a place in our chronicle of progress. It is too often forgotten that the essence of this Museum is its technological character. As a Museum of *Practical* Geology it aims primarily at showing how the minerals and rocks of this kingdom—and secondarily those of other countries—may be utilized for industrial purposes. In this way it differs essentially from the British Museum. If the student is in quest of a rare mineral species, or a specially fine crystal, he should seek it in

---

* 'Memories of the British Museum,' by Robert Cowtan. 1872, p. 64.

† 'The British Museum, Historical and Descriptive.' Edinburgh, 1850, p. 114.

Cromwell Road; but if he wants information about the character of an ore, or an ornamental stone, or a building material, he may be confidently referred to Jermyn Street. So far as the palæontological collections are concerned they are specially intended to illustrate and justify the maps of the Survey; they are, therefore, exclusively British, while those at the British Museum are cosmopolitan; and they are arranged stratigraphically with a subordinate zoological classification, whereas at the British Museum the leading arrangement is zoological and only the subsidiary classification stratigraphical. The more closely the collections in the two museums are compared the more clearly will it be seen that they are in no sense duplicates; there is little or no overlap between them; each museum has its own sphere—the one is complementary to the other; and there can be no question that geological progress has been greatly facilitated by the existence of the two museums with distinct aims.

Social Geology.

Turning from the means of instruction offered by museums to that derived from the companionship of men of kindred tastes associated in the form of learned bodies,* our attention naturally centres in the Geological Society. In 1837 this Society had reached the discreet age of thirty. Founded in 1807, with many of the characteristics of a club, and meeting, curiously enough, as we meet now, on the first Friday in each month, it narrowly escaped being strangled in its cradle by a fit of jealousy on the part of the Royal Society. But having survived this incident it rapidly and healthily developed; the vigour of its growth being sufficiently attested by the fine series of volumes which it had published even in 1837. When removed from Somerset House, where it had been located since 1828, to the rooms which it at present occupies at Burlington House, the history of the Society was ably sketched by Dr. John Evans in the Presidential Address of 1875.† Within the present session we have had the pleasure of hearing in this room a valuable address from the distinguished geologist who at present occupies its Presidential seat,—an incident which I will venture to interpret as expressive of the good feeling with which the Society regards the Association.

---

* See Ami Boué: "Ueber den Associationsgeist als Mittel zur Beförderung der Wissenschaften."

† 'Quart. Journ. Geol. Soc.,' Vol. xxxi.

As to our own Association, I need only remind you that on its coming-of-age in 1880 Professor Rupert Jones read from this Chair a most interesting and complete history of ourselves.* The annals of the Association since that time have happily shown a record of uninterrupted prosperity. Mr. B. B. Woodward has favoured me with a statistical statement showing our steady development. To this energetic officer we are also indebted for having prepared a topographical list of our Members, which will very shortly be issued. From this list it appears that at present .the Association does not number among its Members any residents in the counties of Durham, Huntingdon, Rutland, Suffolk, and Monmouth. Let us hope that by this time next year these counties—some of them offering attractive fields for geological study—may be duly represented in our roll.

Mr. Woodward has suggested—and I cheerfully support his suggestion—that it would be desirable to stimulate our Members—especially those in the provinces—to communicate to the Secretary short notices of any new sections in their neighbourhood, and the Association might thus easily become a central registry for geological information from all parts of the kingdom. It has often occurred to me that the general interest in our proceedings would be increased and their usefulness extended if a larger number of Members could be induced to take an active part in its evening meetings. Members should be encouraged to exhibit specimens, even if they suggest nothing original, and such exhibitions might advantageously occupy a considerable part of some of our meetings, as similar exhibitions frequently do at certain Archæological Societies. In this way we should be carrying out the great function for which this Association was instituted,—the diffusion of a knowledge of geology. The educational character of our body should ever be borne in mind, because herein lies the chief difference between this Association and the Geological Society, a difference which renders any suspicion of jealousy impossible. Investigation is the prime object of the Society ; exposition of the Association. If the Society represents the fountain head of geological wisdom, we rather represent the cistern which receives this knowledge from its source and distributes it in a convenient form, rendering it accessible to many who would find it less easy to drink directly from the primal fount. Such has been the useful if unambitious work of the Association through the last three decades of the Victorian age. May it be long and faithfully maintained!

---

* 'Proc. Geol. Assoc.,' Vol. vii, p. 1.

The International Geological Congress.

Before concluding this address it may not be out of place to remind you—lifting our eyes for a moment from the past to the future—that next year will be a year of exceptional interest to British geologists. Somewhere about next September the International Geological Congress will hold for the first time its triennial meeting in London. It will then be our lot—smarting under the inherited curse of Babel—to receive representatives of our science from all quarters of the earth, and to do our best to render their meeting a meeting of pleasure and of profit. It seems to me that 1888 will be a singularly fit year for such a gathering in this country, inasmuch as exactly a century will then have passed since Hutton laid the foundation of modern geology by the publication of his classical 'Theory of the Earth.' That work, it is true, was not issued in an independent and expanded form until 1795; but it was in the year 1788 that the earliest sketch of the Theory appeared in the first volume of the Transactions of the Royal Society of Edinburgh. The tenets then and there enunciated by Hutton, afterwards illustrated by Playfair, and subsequently modified by Lyell, have received world-wide acknowledgment, and it seems well that geologists from all countries should visit our land to celebrate the centenary of so interesting an event. It is by a happy accident that this hundredth anniversary will coincide with the meeting of the Congress.

Let me remind you that the threefold object of the Congress is to secure uniformity in the nomenclature, the classification, and the cartography of geology. Such a want was felt even before the commencement of the Victorian epoch. Conybeare, in his 'Report on the Progress of Geology,' presented to the British Association in 1832, expressed his regret that the works of English and foreign geologists are sometimes "obscured from the want of a simple and uniform terminology of classification which should be generally adopted by geologists," and he proceeded to observe that "it would be one of the advantages of a scientific reunion" if "such discussions were entered into as might tend to promote this object; should any leading foreigners be present, such a design appears by no means chimerical."*

* 'Rep. Brit. Assoc.,' Oxford, 1832, p. 405.

Some years afterwards a more ambitious project of an International Congress for Science in general was submitted to the British Association by Murchison and Sabine. "An occasional more extensive intercourse of a similar nature to be repeated at certain intervals is greatly to be desired," and they proceeded to advocate "the formation of a general Congress of Science," with Humboldt as the President.* In so far as geology is concerned, this idea is about to be realized by the forthcoming meeting of an International Congress.

It is for the geologists of this country to decide what sacrifice they are disposed to make for the purpose of ensuring success to the Congress, and thus forging a link in the intellectual chain which binds them to their Continental and American brethren. While leaving to older and more influential bodies the details, may some part in the reception, however small, be played by the Members of the Geologists' Association!

ORDINARY MEETING.

FRIDAY, DECEMBER 2ND, 1887.

F. W. RUDLER, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association:—F. Chapman; Miss C. E. Cross; H. A. Miers, M.A., F.G.S.; G. F. Monckton; J. Porter, B.E.; Miss S. M. Rumsey; and W. Thomas.

The following paper was then read:—'On the Vertebrate Fossils of the English Chalk,' by Mr. A. SMITH WOODWARD, F.G.S.

There were exhibited:—

Vertebrate remains from the Chalk of Burham, Kent, exhibited by Mr. S. J. HAWKINS, F.G.S.

Encrinites and other fossils, exhibited by Mr. J. WOOD.

Palatal tooth of *Ptychodus*, from the Chalk-rock, exhibited by Dr. MORISON.

---

* 'Rep. of Brit. Assoc. for 1840,' p. xlvii.

Portion of tooth of *Mosasaurus*, from the Upper Chalk of Norwich, exhibited by Mr. B. B. **Woodward**, F.G.S.

Recent Conglomeratic Boulder (pebbles in clay), from the Isle of Wight, exhibited by Mr. E. **Litchfield**.

A Synopsis of the Vertebrate Fossils of the English Chalk.

By A. Smith Woodward, F.G.S., F.Z.S., of the British Museum (Natural History).

I. Introduction.

Since the publication of the revised edition of Dixon's 'Geology and Fossils of Sussex,' in 1878, no synoptical review of the vertebrate fossils of the English Chalk appears to have been attempted; and with the exception of the elaborate (though not critical) synopsis of genera in Mr. Etheridge's new edition of Phillips' 'Manual,' students of Cretaceous palæontology can still find no other concise treatise on the subject. Much advance, however, has been made within the last ten years in our knowledge of later Mesozoic life; and I propose in the present communication to offer a brief epitome of the facts in regard to the Vertebrata of the period, yielded by the well-known uppermost division of the Mesozoic strata in Western Europe. The 'Proceedings' of the Association afford a most appropriate medium for the publication of such a review, so many of the Members being interested in the treasures continually disinterred from the numerous chalk pits of the South of England. And I have fortunately been able to compare with all that has been written the unrivalled series of original specimens in the British Museum, and the collection of Henry Willett, Esq., F.G.S., of Brighton, besides many other fossils in the Museum of Practical Geology, Jermyn Street, the Woodwardian Museum, Cambridge, and the private cabinets of Mr. S. J. Hawkins, F.G.S., and other Members of this Association.

The following account is thus, to a certain extent, an independent revision of the old vertebrate fauna in question; though it must be admitted that the magnitude of the subject renders it necessarily sketchy and incomplete. If, however, it enables the fortunate discoverers of such fossils the more readily to determine them, and to recognize the value of certain specimens as throwing light upon various still obscure points, this slight endeavour may not be without value in palæontological progress; and I have attempted, as far as possible, to unravel synonymy and correct old errors resulting from the study of imperfect material. The summary of the literature of the subject is also as yet a desideratum, and to make this tolerably complete the title of each work or memoir is quoted *in extenso* upon its first mention, though subsequently abbreviated.

In the midst of so much that is technical it will be impossible to enter at length into many general questions or elementary considerations; and before consulting the descriptive notices of the various fossils it will thus be necessary for those who are not already versed in the rudiments of vertebrate anatomy and zoology to study some elementary treatise on the subject, in addition, if possible, to the articles upon Fishes and Reptiles in the new (ninth) edition of the 'Encyclopædia Britannica.' Dr. Albert Günther's 'Introduction to the Study of Fishes' (Edinburgh, 1880) is also an indispensable work of reference in connection with the Class of which it treats.

II. Fossil Reptiles of the Chalk.

The Reptilian remains of the Chalk are only few and fragmentary, but there are representatives of all the orders characteristic of later Mesozoic times, except the Crocodilia.

Order Chelonia.

As might be expected, the Chelonian remains of the Chalk appear to be all referable to allies of the Turtles, adapted for marine life. The first trace of the order in the English Chalk was recognized in 1836, by Dr. Buckland, who briefly noticed the broken symphysis of a mandible from Dr. Mantell's collection, in his 'Bridgewater Treatise.'*

Genus *Chelone*, A. Brongniart.

To the genus *Chelone* itself may probably be referred the fragmentary remains of a large Turtle, nearly, if not quite, equalling in size the *Chelone Hoffmanni** (= *C. Camperi*, Owen) of Maastricht. Prof. (Sir Richard) Owen has, indeed, provisionally associated some English fossils † with this species; and these include two large plates of the carapace (considered as probably "marginals"), besides a connected series of five other marginals, and two ribs and costal plates, all from the Chalk of Kent. Limb-bones, and probably jaws, of Turtles, have also been discovered in the same beds.

---

* Rev. W. Buckland, 'Geology and Mineralogy,' 2nd edit., 1837, Vol. ii, p. 67, Pl. xliv, Fig. 3*d*.

Genus *Cimoliochelys* (Owen), A. S. W.

In 1841‡ Prof. (Sir Richard) Owen described four marginal plates of a small Chelonian, from the Chalk of Burham, Kent, as probably "referable to that family of Chelonia which lives in fresh-water or estuaries;" about the same time, § Dr. Mantell made known the almost entire carapace, and parts of the plastron, of the same animal, under the name of *Emys Benstedi;* and somewhat later, ‖ Owen examined the new materials, and arrived at the conclusion that they indicated a truly marine form, which must be referred either to *Chelone* or to "a new sub-genus (*Cimochelys*) of marine Turtles having a closer affinity to the Emydes than the typical species." Still later, ¶ a detailed description and discussion of all available specimens led to the conclusion that, though small, the fossils pertained to adult individuals, and that there could be no longer any doubt as to their marine character.

The carapace of the Chelonian in question is oval in shape, with a pointed posterior extremity, and no known specimens are more than six inches in length. The marginal plates are well-developed, but the costals, eight in number,** are not complete, thus leaving fontanelles between their extremities, as in the Turtles and in the young and immature individuals of Emydians and Tortoises. The plastron is no more complete than in the Turtle ; and the coracoid bone also agrees with that of this marine type. The skull is still unknown, unless *Rhinochelys*[*] eventually proves to be identical, and the limb-bones yet remain to be discovered.

---

* For detailed description and figures of this species see T. C. Winkler, 'Des Tortues fossiles conservées dans le Musée Teyler,' 1869. Since the reading of the present paper Dr. Georg Baur ('Science,' Vol. xi, 1888, p. 144) has proposed to place *C. Hoffmanni* in a distinct genus, *Allopleuron*, on account of the small development of the costal plates and the slenderness of the marginals.

† R. Owen, "Monograph of the Fossil Reptilia of the Cretaceous Formations," 'Mon. Pal. Soc.,' 1851, pp. 9-11, Pl. v. Also R. Owen, 'History of British Fossil Reptiles,' Vol. i, p. 163; Vol. ii, Pls. 45, 46 (Chelonia), Pl. ix, Figs. 5, 6 (Lacertilia).

‡ R. Owen, "Description of the Remains of a Chelonian Reptile from the Chalk," 'Trans. Geol. Soc.' [2], Vol. vi (1842), p. 412, Pl. xxxix, Fig. 5.

§ G. A. Mantell, "On the Fossil Remains of Turtles discovered in the Chalk Formation of the S. E. of England," 'Phil. Trans.,' 1841, pp. 153-158, Pls. xi, xii.

‖ R. Owen, "Report on British Fossil Reptiles," Part ii. 'Rep. Brit. Assoc.,' 1841, p. 176.

¶ R. Owen, 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 4-8, Pls. i.-iii.

** Wrongly shown as ten in Mantell's Pl. xii, Fig. 2, *loc. cit.*

It ought to be added that Rütimeyer[†] regards these fossils as most probably immature individuals of freshwater forms. My colleague, Mr. G. A. Boulenger, however, considers that the shape of the carapace and the well-developed character of the marginal plates prove that the animals are adult, and unmistakeably allied to the Turtles; while the narrowness of the neural plates and other features will render the adoption of Owen's distinct name, *Cimo[lio]chelys*, justifiable.

Though not hitherto detected, I am able to state that another Chelonian Chalk fossil has been figured by Dixon[‡] as the jaw of a Sun-fish (*Orthagoriscus*). The specimen is preserved in the British Museum, and is undoubtedly the dentary bone of a Chelonian reptile; as suggested to me by Prof. Seeley, it probably belongs to the type in which the dentary bones are united at the symphysis by a persistent suture—a type already recognized in the Eocene Tertiaries.[§]

Order SAUROPTERYGIA.

Genus *Polyptychodon*, Owen.

Not uncommon fossils of the Chalk and other Cretaceous formations are some robust conical teeth, cylindrical in section, which have the enamelled surface of the crown ornamented by prominent, closely-set longitudinal ridges. To these, in 1841,[‖] Prof. (Sir

---

[*] H. G. Seeley, "Index to Fossil Reptilia, etc., Woodwardian Museum," 1869, p. 25. *R. pulchriceps* = *Chelone pulchriceps*, Owen, 'Mon. Foss. Rept. Cret. Form.,' 1851, p. 8, Pl. vii*a*, Figs. 1-8.

[†] L. Rütimeyer, "Ueber den Bau von Schale und Schädel bei lebenden und fossilen Schildkröten," 'Verh. naturf. Ges. Basel,' Vol. vi (1873), p. 118.

[‡] F. Dixon, 'Foss. Suss.,' First edit., p. xiii, Pl. xxxii, Figs. 3, 4. *Orthagoriscus* is rightly omitted in Mr. E. T. Newton's list in the second edition ; but the figure is still labelled as before, though erroneously stating that the specimen is "recent."

[§] H. G. Seeley, "Note on some Chelonian Remains from the London Clay," 'Ann. and Mag. Nat. Hist.' [4], Vol. viii (1871), p. 231.

[‖] R. Owen, "Rep. Brit. Foss. Rept. ii," 'Brit. Assoc. Rept.,' 1841, p. 156. Also R. Owen, 'Odontography,' 1840-45, Vol. ii, p. 19, Pl. lxxii, Figs. 3, 4.

Richard) Owen applied the name of ***Polyptychodon*** (many-ridged tooth) in allusion to the last-named character; and our knowledge of the nature of the animal to which they belonged has since been increased by other discoveries, though much yet remains to be learned as to the minor features in its osteology. The teeth were originally referred to "Sauria incertæ sedis," but the subsequent discovery of a fragment of jaw showing their implantation in distinct sockets led to the reference of *Polyptychodon* to the crocodiles.* Some Saurian bones from the Lower Greensand of Hythe, Kent, were also regarded as probably belonging to the same animal,† though now known to be truly Dinosaurian.‡ And the still later discovery of a portion of the skull in association with the jaws and teeth, in the Chalk of Somersetshire, has shown that the genus is truly Sauropterygian, allied to *Plesiosaurus*.§ The characters of the vertebræ likewise support this determination.||

Two species are recognized, the teeth of *P. interruptus* being the commonest, and differing from those of *P. continuus* in "the greater proportion of the ridges which stop short of the apex of the crown." It remains uncertain, however, whether these variations in superficial markings did not occur in different parts of the dentition of the same individual. In the ordinary broken dental crowns the tooth-substance has often become resolved into superimposed conical layers by fracture.

Genus *Plesiosaurus*, Conybeare.

Teeth and vertebræ and other remains of Plesiosaurians, provisionally referred to *Plesiosaurus* itself, are occasionally met with in the Chalk, and Sir Richard Owen has named three supposed species, *P. Bernardi* (founded upon a cervical vertebra from the Upper Chalk of Houghton, near Arundel, Sussex),¶ *P. con-*

---

* R. Owen, in Dixon's 'Foss. Suss.,' 1850, pp. 378, 379, Pl. xxxvii, Figs. 16, 17; Pl. xxxviii, Fig. 3.

† R. Owen, 'Mon. Foss. Rept. Cret. Form.,' pp. 47-55, Pls. xii, xiii.

‡ *Dinodocus Mackesoni*, R. Owen, 'A History of British Fossil Reptiles,' Vol. ii, p. ix.

§ R. Owen, 'Mon. Foss. Rept. Cret. Form.,' Suppl. iii (1860), pp. 20-22, Pl. iv, Figs. 1-3.

|| R. Owen, *op. cit.*, Suppl. iii, pp. 22-25, Pl. v, Figs. 1, 2; Pl. vi. Also H. G. Seeley, "On an Associated Series of Cervical and Dorsal Vertebræ of *Polyptychodon*, from the Cambridge Upper Greensand," 'Quart. Journ. Geol. Soc.,' Vol. xxxii (1876), pp. 433-436.

¶ R. Owen, in Dixon's 'Foss. Suss.,' 1850, pp. 396-398, Pl. xl. Also 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 60, 61, Pl. xviii. Mr. William Davies permits me to state that he considers these and the other supposed Plesiosaurian bones as most probably referable to *Polyptychodon*.

strictus (represented by the centrum of a cervical vertebra from Steyning, Sussex),* and *P. Smithii* (to which are referred paddle-bones and a cervical vertebra from the Kentish Chalk†).

The tooth of *Plesiosaurus* is slender and cylindrical in section, and the enamelled crown is slightly curved, gradually tapering to a point; the surface is marked with longitudinal ridges of different lengths, none extending quite to the apex. The tooth is, in fact, essentially similar to that of *Polyptychodon*, though usually more elongate and slender.

Order ICHTHYOPTERYGIA.

Genus *Ichthyosaurus*, König.

The first remains of Ichthyosaurians discovered in the English Chalk were made known by Prof. (Sir Richard) Owen in 1839,‡ who recorded a portion of a lower jaw, with teeth, from the Lower Chalk between Folkestone and Dover; but neither these fossils nor the teeth subsequently described and figured in Dixon's 'Fossils of Sussex' (p. 400, Pl. xxxix., Fig. 10), were considered as affording definite evidence of the specific distinctness of the animal from the Liassic *I. communis*. In 1845,§ however, Mr. James Carter discovered more satisfactory specimens in the Lower Chalk of the neighbourhood of Cambridge, and these enabled him to refer it decidedly to a previously unknown species, named *I. campylodon*, in allusion to the strong inward curve of the crowns of the lower teeth. Still later,‖ Sir Richard Owen published detailed descriptions and figures of Mr. Carter's fossils, and of others discovered near Dover; so that the characters of the dentition, upper and lower jaws, and some of the vertebral centra, are now tolerably well known.

The teeth have round, longitudinally-ridged crowns, very similar to those of *Polyptychodon*; but they are readily distinguished by the great diameter of the base, which becomes compressed towards its lower extremity, and is not smooth but coarsely grooved.

---

* R. Owen, in Dixon's 'Foss. Suss.,' 1850, p. 398, Pl. xxxvii, Figs. 6, 7. Also 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 61, 62, Pl. ix, Figs. 6, 7.

† R. Owen, 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 63, 64, 66, 67, Pls. xvii, xix. The name appears to be first given in the Index to Vol. iv of Owen's 'Hist. Brit. Foss. Rept.,' where the plates are repeated.

‡ R. Owen, "Rep. Brit. Foss. Rept., i," 'Brit. Assoc. Rep.,' 1839, p. 126.

§ J. Carter, "Notice of the Jaws of an *Ichthyosaurus* from the Chalk in the neighbourhood of Cambridge," 'Brit. Assoc. Rep.,' 1845, Trans. Sect., p. 60. Also J. Carter, "On a New Species of *Ichthyosaurus* in the Chalk," Charlesworth's 'London Geological Journal,' 1846, pp. 7-9.

‖ R. Owen, 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 69-80, Pl. iv, Figs. 1-10, 13-16, Pls. xxii, xxiii, xxv, xxvi.

Order PYTHONOMORPHA.

This is a group of marine reptiles, comprising the well-known *Mosasaurus* and its allies, placed by Owen* among the Lacertilia (Lizards), but regarded by Cope† as a distinct order, having Lacertilian affinities, though most nearly related to the Ophidia (Snakes). Very few remains have hitherto been met with in the English Chalk, but the discoveries of nearly complete skeletons in America and in Holland and Belgium have revealed all the more important features of its osteology. The first fossils detected in this country were some vertebræ from the Upper Chalk of Lewes, figured and described by Dr. Mantell, in 1833 ‡; and subsequent discoveries have been chronicled by Charlesworth, Owen, Bayfield,§ and others.

Genus *Mosasaurus*, Conybeare.

The teeth of the typical genus *Mosasaurus* have a conical crown fixed upon a stouter base, which is relatively long and anchylosed to the jaw-bones. The crown is smooth, enamelled, and more or less laterally compressed; and a pair of opposite longitudinal ridges divide it into two faces, which are sometimes of corresponding size though sometimes very unequal. Occasionally the sharp ridges exhibit feeble serrations. Teeth of all the varied forms met with in the *M. Camperi* (= *M. Hoffmanni*) of Maastricht, are discovered in the upper divisions of the English Chalk, and the numerous vertebræ occurring in the same beds are likewise closely similar to those of this well-known fossil.

Some of the teeth from the Norfolk Chalk were originally referred by Mantell‖ "to an unknown reptile or to a sauroid fish," and they were first described under the name of *Leiodon anceps*, by

---

* R. Owen, 'On the Rank and Affinities of the Mosasauridæ,' 'Quart. Journ. Geol. Soc.,' Vol. xxxii (1877), pp. 682-715. Also *ibid.*, Vol. xxxiv (1878), pp. 748-752.

† E. D. Cope, "The Vertebrata of the Cretaceous Formations of the West," 'Rept. U.S. Geol. Surv. Territ.,' Vol. ii (1875), pp. 113-130.

‡ G. A. Mantell, 'Geology of the South-east of England,' 1833, p. 146.

§ T. G. Bayfield, "Discovery of the Skeleton of *Leiodon anceps* in the Chalk at Norwich," 'Geol. Mag.,' Vol. i (1864), p. 296.

‖ G. A. Mantell, 'Wonders of Geology,' ed. 1839, Vol. i, p. 339.

Prof. (Sir Richard) Owen,* who felt justified in regarding the teeth with symmetrically compressed crowns as pertaining to the mandible and the maxilla, thus showing a generic divergence from the true *Mosasaurus*, in which the corresponding teeth (though not those of the pterygoid bones) have less compressed unsymmetrical crowns. At present, however, the evidence is not conclusive, and we prefer, with Mr. Edward Charlesworth, to place the specimens in the genus *Mosasaurus* itself, until the discovery of more satisfactory materials renders a certain determination possible.† There does not seem to be much proof of the generic identity of the more complete American and New Zealand Fossils subsequently referred by Cope‡ and Hector§ to *Leiodon;* and the English teeth must thus be known as *Mosasaurus anceps.* It is true that Charlesworth claims to have described one of the specimens figured by Owen (1840) at a British Association meeting in 1836, under the name of *M. stenodon,* but this must necessarily become a synonym since no printed notice appeared until ten years later.‖

Another supposed Pythonomorph from the chalk of Offham, Sussex, was described by Owen, in 1850,¶ upon the evidence of the jaws and teeth. The type-specimen, however, is in the collection of Mr. Henry Willett, of Brighton, and, as recognized by Prof. O. C. Marsh and Mr. William Davies,** it really pertains to a large fish, *Pachyrhizodus.* The truly Mosasaurian vertebræ, ascribed in error to the possessor of these jaws,* may doubtless be referred to *M. anceps*.

---

* R. Owen, 'Odontography,' p. 261, Pl. lxxxii, Figs. 1, 2. Also 'Mon. Foss. Rept. Cret. Form,' 1851, pp. 42-45, Pl. ix*a*. R. Owen, "Restoration of *Leiodon anceps*," 'Ann. and Mag. Nat. Hist,' [5], Vol. iv (1878), pp. 53-61, Pl. viii; and 'Supplement to Restoration of *Leiodon anceps*,' *ibid.* [5], Vol. v, pp. 177-181, Pl. viii.

† Since the reading of this paper Mr. R. Lydekker has studied the known specimens, and is of opinion that the genus *Leiodon* ought to be adopted for the compressed teeth, while an uncertain Mosasaurian genus, perhaps *Clidastes*, is represented by the others.

‡ E. D. Cope, 'Vert. Cret. Form. West,' 1875, pp. 160-178; with plates.

§ J. Hector, "On the Fossil Reptilia of New Zealand," 'Trans. N. Zealand Instit.,' Vol. vi (1874), p. 351.

‖ E. Charlesworth, "On the Occurrence of a species of *Mosasaurus* in the Chalk of England, and on the Discovery of Flint within the Pulp-cavities of its Teeth," 'London Geol. Journ.,' 1846, pp. 23-32, Pls. iv, v.

¶ R. Owen, in Dixon's 'Foss. Suss.,' pp. 380-383, Pl. xxxvii, Fig. 1. Also 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 31-35, Pl. ix, Fig 1.

** For this unpublished information I am indebted to my friend, Mr. Edward Crane, F.G.S., Chairman of the Brighton Museum Committee. There can be no doubt as to the correctness of the amended interpretation of the fossil.

Order LACERTILIA.

Remains apparently of true Lizards are rare in the Chalk, but Sir Richard Owen has recognized three extinct genera, *Rhaphiosaurus*, *Dolichosaurus*, and *Coniosaurus*.

Genus *Rhaphiosaurus*, Owen.

A fragment of mandible from the Lower Chalk, near Cambridge, forms the type-specimen of the genus and species, *Rhaphiosaurus subulidens*, Owen;† and no parts of the animal beyond jaws and teeth have hitherto been described. The teeth are slender and awl-shaped, hence the name of the genus. They are "attached by anchylosis in a single series to the bottom of a shallow alveolar groove, and to the inner side of an outer wall or parapet of the same groove, thus corresponding with that type of saurian dentition called 'pleurodont' among modern lizards." The published figures, however, regarded in the light of modern facts, are suggestive of considerable doubts as to the reptilian nature of the fossil.

Genus *Dolichosaurus*, Owen.

This genus is so named on account of its elongate snake-like form, and a tolerably complete skeleton, from the Lower Chalk of Burham, Kent, has been described by Sir Richard Owen.‡ The hinder portion of this fossil was at first provisionally associated with *Rhaphiosaurus*, § and was presented by Sir Philip de M. Grey Egerton to the British Museum; the anterior portion has also been acquired for the National Collection, being one of the fine series of Burham fossils collected by the late Mrs. Smith, of Tunbridge Wells.

---

* R. Owen, in Dixon's 'Foss. Suss.,' pp. 383, 384, Pl. xxxvii, Figs. 2-5, Pl. xxxix, Figs. 7-9. Also 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 40, 41, Pl. viii, Figs. 1-3; Pl. ix, Figs 2-5.

† *Rhaphiosaurus*, R. Owen, "Description of the Vertebral Column [etc.] of a small Lacertine Saurian from the Chalk," 'Trans. Geol. Soc.' [2], Vol. vi, (1840), p. 413, Pl. xxxix, Fig. 3. *R. subulidens*, Owen, 'Brit. Assoc. Rep.,' 1841, p. 190. *R. lucius*, Owen, Dixon's 'Foss. Suss.,' 1850, p. 385-6, Pl. xxxix, Figs. 1-3. *R. subulidens*, Owen, 'Mon. Foss. Rept. Cret. Form.,' 1851, pp. 19, 20, Pl. x, Fig. 5, 6.

‡ R. Owen, in Dixon's 'Foss. Suss.,' pp. 388-395, Pl. xxxviii, Figs. 1, 2; Pl. xxxix, Fig. 4. Also 'Mon. Foss. Rept. Cret. Form.,' pp. 22-29, Pl. x, Figs. 1-4.

§ R. Owen, 'Trans. Geol. Soc.' [2], Vol. vi (1840), p. 412, Pl. xxxix, Fig. 4.

The head of *Dolichosaurus* is relatively small, and the teeth are long smooth cones, with rounded blunt tips. The vertebræ are united by a "peg-and-socket" arrangement (zygosphene and zygantrum) of the neural arch,* such as is met with in Ophidia (snakes) and certain Pythonomorpha. The fore and hind limbs are well developed, and the single known species is named *D. longicollis*, in allusion to the great length of its neck. With regard to the affinities of the animal, Sir Richard Owen concludes that its skeleton exhibits all the characteristic features of a lizard. There is most divergence in the neck, where "the Ophidian type is rather followed in the number and size of the vertebræ, and in the size and shape of the ribs: a less decided approach, but one still indicating an affinity to the Ophidians, is made by the unusual length of the slender trunk, which includes, from the skull to the sacrum, not fewer than fifty-seven vertebræ, and is not less than eighteen inches in length. The smallness of the head accords with the long and slender proportions of the neck, and must have added to the snake-like appearance of this early example of procœlian lizard. But the complete and typically Lacertian organization of the scapular and pelvic arches, and of their locomotive appendages, prove that the *Dolichosaurus* was more strictly a lacertine Saurian than the existing genera, *Pseudopus*, *Bipes*, and *Ophisaurus*, which effect the transition from the Lizards to the Snakes."

Genus *Coniosaurus*, Owen.

Coniosaurus crassidens, the only known species of this genus, was founded† upon fragments of the jaws and teeth, associated with vertebræ, from the Lower Chalk of Clayton, near Brighton. "The dentary bones contain from 18 to 20 teeth; the anterior five or six teeth are slender, slightly recurved, pointed or laniariform; the rest progressively increase in thickness as they are placed further back, expanding above the neck, slightly compressed laterally, most convex inwardly, with an anterior border which is more prominent and curved than the posterior; the anterior margin is further characterized by a longitudinal groove on its outer side. Some of the posterior teeth show a slight longitudinal indent near the posterior obtuse border: and the last molar is smaller and more obtuse than the others. The enamel is very finely wrinkled. The teeth are closely and rather obliquely arranged; the long simple roots are anchylosed to the bottom of the shallow alveolar groove and to the inner side of the outer wall."

---

* H. G. Seeley, 'Phillips' Manual of Geology,' revised edit., Vol. i (1885), p. 512.

† R. Owen, in Dixon's 'Foss. Suss.,' pp. 386-388, Pl. xxxvii, Fig. 18-20. Also 'Mon. Foss. Rept. Cret. Form.,' pp. 21, 22, Pl. ix, Figs. 13-15.

Order PTEROSAURIA.

The hollow bones of the Pterodactyles are so fragile, that the remains of the Pterosaurian order discovered in the Chalk are all of a most fragmentary character. Up to the present time, no evidence of toothless forms like those from the American Cretaceous has been discovered in this formation, and all the English fossils may perhaps be referred to a single genus, *Ornithocheirus*.

Genus *Ornithocheirus*, Seeley.

The history of the acquisition of our still imperfect knowledge of Chalk Pterodactyles is long and intricate. The first relics of these animals, comprising the shaft of one long bone and the articular end of another from the Chalk of Kent, were described by Owen in 1840* as "Ornitholites," *i.e.*, as referable to birds. Five years later Dr. Bowerbank† discovered a fragment of the jaws and teeth of an undoubted Pterodactyle, with portions of hollow limb-bones, in the Lower Chalk of Burham, and associating with these fossils the supposed bird-remains of Owen, proposed to name the new species thus indicated. *Pterodactylus giganteus.* Shortly afterwards, in 1846,‡ Prof. (Sir Richard) Owen re-affirmed his previous conclusions, and suggested that the "bird" might receive the name of *Cimoliornis diomedeus*, adopting as specific name the term used by Gervais § in alluding to these fossils as representing an "*Osteornis*."‖ In 1847¶ Dr. Bowerbank made a further contribution to the subject, and four years later yet another,** adding a new species, *P. Cuvieri*, upon the evidence of a fragment of an elongated jaw, also from Burham. Meanwhile Sir Richard Owen acknowledged his original mistake, but first pointed out[*] that two species, a larger and a smaller, must have been included under *P. giganteus*; and believing that the latter name applied especially to the so-called "bird remains" which he had at first described, suggested that Dr. Bowerbank's earliest fragment of jaw and the smaller limb-bones should be named *P. conirostris*. In 1851,[†] however, recognizing the impossibility of definitely associating the various detached limb-bones with the jaws, Sir Richard Owen adopted the name of *P. giganteus* for the specimen he had termed *P. conirostris*, redescribed the jaw-fragment of *P. Cuvieri*, and made known portions of the snout of a third previously unrecognized species, *P. compressirostris*; he also added separate descriptions and figures of the limb-bones already discovered, under provisional determinations. No further contribution to the subject seems to have been made before 1870, when Prof. Seeley[‡] definitely showed that there were similar fossils in the Cambridge Greensand and that these represented a genus quite distinct from *Pterodactylus*, which might be named *Ornithocheirus*. Among other important features, it was pointed out that the latter genus differed from the former in having the foremost pair of teeth projecting forward in the upper jaw, and placed at a higher level than all those behind. Sir Richard Owen's subsequent attempt[§] to supplant the name *Ornithocheirus* (bird-hand) by the new term *Coloborhynchus* (stunted-snout), on account of the alleged inappropriateness of the first, is scarcely justifiable; and the Chalk species must therefore be known respectively as *Ornithocheirus giganteus*, *O. Cuvieri*, and *O. compressirostris*.

---

* R. Owen, "Description of the Remains of a Bird from the Chalk," 'Trans. Geol. Soc.' [2], Vol. vi (1840), p. 411, Pl. xxxix, Figs. 1, 2.

† J. S. Bowerbank, "On a new species of Pterodactyl found in the Upper Chalk of Kent," 'Quart. Journ. Geol. Soc.,' Vol. ii (1846), pp. 7, 8, Pl. i.

‡ R. Owen, 'British Fossil Mammals and Birds,' 1846, pp. 545-548; woodcuts.

§ P. Gervais, 'Thése sur les Oiseaux Fossiles,' 1844, p. 38 (according to Owen).

‖ "This term is applied by M. Gervais, not generically to the fossil in question, but generally to all fossil bones of birds." (Owen.)

¶ J. S. Bowerbank, "Microscopical Observations on the structure of the Bones of *Pterodactylus giganteus* and other Fossil Animals," 'Quart. Journ. Geol. Soc.,' Vol. iv (1848), pp. 2-10, Pls. i, ii.

** J. S. Bowerbank, "On the Pterodactyles of the Chalk Formation," 'Proc. Zool. Soc.,' 1851, pp. 14-20, Pl. iv.

The bones of Pterodactyles may always be recognized by their hollowness and their very thin, extremely dense walls. The detached teeth are not readily distinguished from those of the fish *Protosphyræna*, found in the same beds; they are long, conical, and laterally compressed, with smooth or delicately striated enamelled crowns.

---

[*] R. Owen, in Dixon's 'Foss. Suss.' pp. 401-404, Pl. xxxviii, Figs. 4-7.

[†] R. Owen, 'Mon. Foss. Rept. Cret. Form.,' pp. 88-104, Pl. xxvii, Figs. 8-10; Pl. xxviii, Figs. 1-7; Pl. xxiv, xxx, xxxi. Also R. Owen, "On a new species of Pterodactyle (*Pterodactylus compressirostris*, Owen) from the Chalk; with some Remarks on the previously described species," 'Proc. Zool Soc.,' 1851, pp. 21-34.

[‡] H. G. Seeley, 'The Ornithosauria,' 1870, pp. 28-94, 112-128. See also H. G. Seeley, "On Evidence of two new Ornithosaurians referable to the Genus *Ornithocheirus*, from the Upper Greensand of Cambridge," 'Geol. Mag.' [2] Vol. viii, 1881, pp. 13-20, Pl. i.

[§] R. Owen, 'Mon. Foss. Rept. Mesoz. Form.,' Pt. 1, 1874, p. 6.

Order DINOSAURIA.

Genus *Acanthopholis*, Huxley.

The only Dinosaurian remains hitherto recorded from the English Chalk have been obtained from the Chalk Marl in the neighbourhood of Folkestone. These fossils indicate a small armoured animal, of a herbivorous character, allied to the Liassic *Scelidosaurus* and the Wealden *Hylæosaurus* and *Polacanthus*, and named by Prof. Huxley* *Acanthopholis horridus*. The type-specimens comprise the basioccipital and basisphenoid bones of the skull, three teeth, several vertebræ, portions of limb-bones, and numerous dermal scutes and spines, all found associated, and now preserved partly in the Museum of Practical Geology and partly in the British Museum. The teeth are triangular and compressed, with a deeply dentated margin; and they have the sides marked by radiating grooves, one extending downwards from each marginal notch. The scutes vary from oval discs, slightly raised in the middle, and hardly more than an inch in diameter, to great spines about nine inches in height, with a base measuring five inches in its longer axis ; and the outer surface of all these is covered with irregular pits and branching grooves suggestive of the original presence of an enveloping soft integument. The vertebræ are slightly biconcave, and, so far as known, have been described in detail by Prof. Seeley.† The last-named palæontologist has also recorded (*loc. cit.*) other remains of *Acanthopholis* from the Cambridge Greensand.

III. FOSSIL FISHES OF THE CHALK.

The Upper Cretaceous Fishes are of great interest on account of the number of forms they include immediately ancestral to the families and genera of existing seas. In this later Mesozoic ichthyic fauna, the marine Ganoids were rapidly becoming extinct ; the Selachians were apparently already differentiated into the families met with at the present day ; while the Teleosteans were very largely of a primitive "generalized" type, though some, like the Berycoids, had advanced to a considerable degree of "specialization."

---

* T. H. Huxley, "On *Acanthopholis horridus*, a New Reptile from the Chalk Marl," 'Geol. Mag.,' Vol. iv, 1867, pp. 65-67, pl. v.

† H. G. Seeley, "On the Vertebral Characters of *Acanthopholis horridus*, Huxley," 'Quart. Journ. Geol. Soc.,' Vol. xxxv, 1872, pp. 596-600 woodcuts.

Order SELACHII.

The Sharks and Rays form a well-characterized order, with a cartilaginous skeleton, having the upper jaw (pterygo-quadrate cartilage) free, and merely suspended to the skull. The teeth are attached only to the membrane enveloping the jaws, and the skin is often armed with dermal tubercles (the so-called "placoid scales") of essentially similar structure. Long spines are often present in front of the dorsal fins, or isolated upon the tail; and the latter is either straight and pointed (*diphycercal*) or at the same time upwardly bent, with an unsymmetrical tail-fin (*heterocercal*). The gill-slits are not covered externally with any fold of skin, and the mouth is rarely terminal, being nearly always placed inferiorly. The vertebral column sometimes remains in its primitive notochordal state, having only chondrified neural and hæmal arches; sometimes there are mere slender rings in the notochordal sheath; often the biconcave vertebral centra are complete. The latter are of three types, first described by Prof. Sir Richard Owen,* and afterwards more accurately determined and named by Dr. Carl Hasse, of Breslau.† In the first, or *cyclospondylic* type, each vertebra may be said to consist of two hollow cones placed end to end, thus generally having the external appearance of being much constricted in the middle; in the second, or *tectospondylic* type, concentric laminæ surround the primitive double-cone just mentioned; and in the third, or *asterospondylic* type, outwardly radiating plates are arranged round the double cone, more or less connected together by concentric laminæ, and giving a star-like appearance to transverse sections of the vertebræ. The "cyclospondylic" is evidently the primitive type, of which the two others are specialized modifications.

The Spiny Dog-fishes (*Spinacidæ*) are cyclospondylic; the Rays, *Pristiophoridæ*, and Angel-fishes (*Squatinidæ*) are tectospondylic; and the *Lamnidæ*, *Carchariidæ*, *Cestraciontidæ*, etc., are asterospondylic. It is thus possible to determine detached Selachian vertebræ approximately, and Dr. Hasse attempts to show that even the various genera and species can be identified.

---

* R. Owen, 'Anatomy of Vertebrates,' Vol. i, 1866, p. 32.

† C. Hasse, 'Das natürliche System der Elasmobranchier,' Jena, 1879-1882. See also K. A. Zittel's 'Handbuch der Paleontologie,' Vol. iii, pp. 61-63.

Selachii Asterospondyli.

Genus *Notidanus*, Cuvier.

This primitive genus of sharks is occasionally represented in the English Chalk—especially in the higher beds—by detached teeth which vary somewhat in form, but apparently belong to a single well characterized species, *N. microdon*, Agass.,* and possibly in part to a second, *N. pectinatus*, Agass.† The lower lateral teeth are most commonly met with, and are easily recognized by their long comb-shaped form; the root has no fangs, but is straight and laterally compressed, and the crown consists of a series of sharp cones, similarly compressed, more or less oblique, placed one behind the other, and diminishing in size as they approach the hinder end. As is always the case in the genus *Notidanus*, the upper teeth are shorter than the lower, and those originally situated in front of the upper jaw often consist merely of a single large, backwardly directed cone, with one or two small denticles behind.‡

In *N. microdon*, the anterior edge of the foremost or principal cusp of the dental crown is slightly serrated, and I have observed no very marked accentuation of this character in any of the large series of Chalk teeth I have had the opportunity of examining, with the exception of a few from the front of the upper jaw. Agassiz, however, made known one example, probably from Sussex, in which the anterior serrations were represented by a series of distinct denticles, and for this type he proposed the name of *N. pectinatus*.

The detached teeth appear to be the only relics of *Notidanus* hitherto recognized in the English Chalk, but a tolerably complete fish, named *N. gracilis*, has been described from the Upper Cretaceous of Mount Lebanon.§

Genera *Hybodus*, Agassiz, and *Synechodus*, A. S. Woodw.

The characters of the teeth and dorsal fin-spines of *Hybodus* are so well known that it is unnecessary to describe them in detail. The

---

* L. Agassiz, 'Recherches sur les Poissons fossiles' (1833-1843), Vol. iii, p. 221, Pl. xxvii, Fig. 1; Pl. xxxvi, Figs. 1-2. A more extended description, with figures, is given in Smith Woodward, "On the Palæontology of the Selachian Genus *Notidanus*, Cuvier," 'Geol. Mag.' [3], Vol. iii (1886), p. 213, Pl. vi, Figs. 10-15.

† L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 221, Pl. xxxvi, Fig. 3. Mr. William Davies suggests that this may be an abnormal tooth of *N. microdon* —a very plausible idea.

‡ See figures in 'Geol. Mag.,' *loc. cit.*

§ J. W. Davis, "On the Fossil Fishes of the Chalk of Mount Lebanon, in Syria," 'Trans. Roy. Dublin Soc.' [2], Vol. iii (1887), pp. 470-1, Pl. xiv, Fig. 1.

Chalk fossils hitherto referred to this perhaps too comprehensive "genus," however, include considerable portions of the cartilaginous skeleton in addition to these less perishable structures, and the whole are suggestive of some interesting considerations in regard to the evolution of the Hybodont sharks. The typical fishes of the genus *Hybodus* from the Lias seem to have had a persistent notochord, while the best known Chalk species shows a well-developed vertebral column, with centra of the "asterospondylic" type; the skull of the later form is less primitive than that of the earlier, and the dentition is also more specialized, the front teeth being quite sharp and prehensile, while the posterior are nearly flat and adapted for crushing. These facts are revealed by the small "*Hybodus*" *dubrisiensis*,*—the only species yet defined from the English Chalk—and the well differentiated character of the vertebral column, among other features, warrants the generic separation of this form from its Jurassic progenitors under the name of *Synechodus*. Whether all the numerous detached teeth which have received names in Bohemia,† and the still unrecorded teeth from the English Chalk, all belong to the same genus, or to *Hybodus* proper, must yet remain undetermined; but it is significant to note that all the known dorsal fin-spines from the Chalk are smooth, the fragments of a ribbed spine described by Agassiz as *Hybodus sulcatus*, from "la craie de Lewes,"‡ being undoubtedly Wealden fossils, and not improbably belonging to *Hybodus basanus*.§

Genus *Drepanephorus*, Egerton.

In 1822 some spines and vertebræ from the Chalk of Lewes were referred by Dr. Mantell to the Teleostean "File-fish," *Balistes*.‖ These were subsequently shown by Prof. Agassiz to be really the remains of a shark, and seemed to him to indicate a form so nearly allied to the living *Spinax* that he proposed the name of *Spinax*

---

* S. J. Mackie, "On a New Species of *Hybodus*, from the Lower Chalk," 'The Geologist,' Vol. vi (1863), pp. 241-246, Pl. xiii. Smith Woodward, "On the Relations of the Mandibular and Hyoid Arches in a Cretaceous Shark (*Hybodus dubrisiensis*, Mackie)," 'Proc. Zool. Soc.,' 1886, pp. 218-224, Pl. xx.

† A. E. Reuss, 'Versteinerungen der böhmischen Kreideformation,' 1845-6. Pt. i, p. 2, Pl. ii, Fig. 20; Pt. ii, pp. 97, 98, Pl. xxi, Figs. 9-17; Pl. xxiv, Figs. 26-28; Pl. xlii, Fig. 7.

‡ L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 44, Pl. x*b*, Figs. 15, 16.

§ S. J. Mackie, *loc. cit.*, p. 242.

‖ G. A. Mantell, 'Fossils of the South Downs,' 1822, p. 229, Pl. xxxiii, Figs. 5, 6.

major.[*] Still later, in 1850, Sir Philip Egerton described some scattered teeth from the Chalk which bore a very close resemblance to those of the living Port Jackson shark, *Cestracion*, and were thus made the type of a new species of that genus, named *Cestracion canaliculatus* in allusion to a small perforation or canal passing obliquely through the root.[†] In 1853 the discovery of more satisfactory specimens proved that the teeth made known by Egerton, and the spines previously described by Mantell and Agassiz, truly belonged to the same fish,[‡] and nineteen years later, in 1872, Sir Philip Egerton reinvestigated the fossils, describing the dentition, spines, vertebral column, and portions of cartilage, and showing that they indicated a Selachian genus distinct from any previously determined.[§] This new form he proposed to term *Drepanephorus* (sickle-bearer), and, following Agassiz, he placed it among the Spiny Dog-fishes in the *Spinacidæ*. The subsequent elaborate researches of Dr. Carl Hasse upon the vertebræ have demonstrated that the fish ought rather to be referred to the *Cestraciontidæ*,[‖] and still more recent studies seem to show that it can scarcely be distinguished from certain later Mesozoic Cestracionts, which have been described as *Acrodus*.[¶]

Of the fish with so long a history, numerous fragmentary relics are met with in the Chalk of almost all localities, as well as in the Gault and Greensand. The dorsal fin-spines are comparatively small, the largest examples not attaining a length of more than five inches; and each individual possessed two of these, one in front of either dorsal fin. These defences are laterally compressed, without posterior denticles, and have the exposed sides covered with smooth shining ganoine, only marked by delicate lines of growth. They exhibit varying degrees of curvature, some—generally the posterior—being nearly straight, and some—generally the anterior—quite sickle-shaped.

The teeth of *Drepanephorus* vary considerably in different parts of the jaw, being arranged exactly as in the living *Cestracion*, the more prehensile anteriorly, and the crushing teeth behind. Each of the former consists of a smooth, sharply-pointed cone, with a pair of large lateral denticles, fixed upon a massive root or base, while the latter are elongate and flattened, with a longitudinal median ridge, from either side of which there descend fine rugæ, passing more or less abruptly into a complex and delicate ornamental network. In the typical species, *D. canaliculatus*, the root of the tooth, as already mentioned, is pierced by an oblique perforation; but I have been unable to ascertain whether such is the case in the larger specimens described by Agassiz under the name of *Acrodus rugosus*,* which may belong to a distinct species.†

---

[*] L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 62, Pl. x*b*, Figs. 8-14.

[†] F. Dixon, 'Foss. Suss.,' p. 365, Pl. xxxii, Fig. 8.

[‡] Sir P. Egerton, "Palichthyologic Notes," 'Quart. Journ. Geol. Soc.,' Vol. ix (1853), p. 281.

[§] Sir Philip Egerton, "Figs. and Descrips. Brit. Org. Remains," Dec. xiii ('Mem. Geol. Surv.,' 1872), Pl. ix.

[‖] C. Hasse, "Paläontologische Streifzüge im British Museum," 'Neues Jahrb.,' 1883, Vol. ii, p. 66.

[¶] *e.g.*, *Acrodus falcifer*, A. Wagner, 'Abh. k. Bayer. Akad. Wiss.,' Cl. ii, Vol. ix pp. 300-4, Pl. v, Fig. 1.

Genus *Acrodus*, Agassiz.

No teeth belonging to the familiar type of *Acrodus* as represented in the Lias, have hitherto been detected in the Chalk, and the most recent examples of this dental form are those of *A. levis*, from the Gault.‡ Some detached teeth have, however, been referred to this genus, and it is impossible to determine, upon such evidence alone, whether forms like Dixon's *A. Illingworthi*§ are not rightly placed here. These teeth sometimes attain a considerable size, more than an inch in length, and many are quite indistinguishable from those usually referred to *Hybodus*; but the discovery of much more satisfactory material must be awaited before any satisfactory determination of these remains can be attempted.

The so-called *Acrodus cretaceus*, Dixon, may almost certainly be referred to *Drepanephorus canaliculatus*||; and *A. rugosus*, Agass., as already remarked, belongs either to the same species, or to a larger form of *Drepanephorus* as yet unrecognized.

Genus *Oxyrhina*, Agassiz.

This is a shark so nearly related to *Lamna* that zoologists ordinarily place the single living species in the latter genus. Agassiz,

---

* L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 148, Pl. xxii, Figs. 28, 29.

† Smith Woodward, "Notes on some Post-Liassic Species of *Acrodus*," 'Geol. Mag.' [3], Vol. iv (1887), p. 104.

‡ Smith Woodward, *loc. cit.*, p. 103 (woodcuts). Since the reading of the paper, Mr P. E. Coombe has presented to the British Museum a tooth from the Chalk of Lewes (No. P. 5398) indistinguishable from *Acrodus levis*, thus adding this species to the Chalk list.

§ F. Dixon, 'Foss. Suss.,' 1850, p. 364, Pl. xxx, Figs. 11, 12; Pl. xxxii, Fig. 9.

|| Smith Woodward, *loc. cit.*, p. 104.

however, considered it convenient to distinguish the fossil teeth under the name of *Oxyrhina*, from the circumstance that, though much like those of the true *Lamna*, they are almost invariably destitute of lateral denticles, and more compressed. The anterior teeth are long and narrow, while those behind gradually become broader, and then shorter and smaller. *O. Mantelli*[*] is the common species of the Chalk, and is also met with occasionally in the Upper Greensand. The full-grown teeth are large and robust, and, though very rarely, show an occasional small lateral denticle. As proved by specimens in the British Museum, some of the hindermost and foremost teeth of this species were described and figured by Agassiz and Dixon under the name of *Lamna acuminata*.[†] Other very robust teeth, of extraordinary dimensions, are known as *O. crassidens*,[‡] perhaps pertaining to a distinct species. There is a fine group in Mr. Willett's collection in the Brighton Museum.

Genus *Odontaspis*, Agassiz.

The teeth of *Odontaspis* differ from those of *Lamna* in being almost cylindrical in section, and they usually exhibit more or less of a sigmoidal curvature. Two small species occur in the Chalk—the one (*O. subulata*[§]) having the teeth quite smooth, the other (*O. rhaphiodon*[‖]) possessing a delicate ornament of minute longitudinal ridges upon the hinder aspect of the crown. The first of these also occurs in the Gault and Greensand, and was originally founded upon a tooth from the Chalk Marl of Quedlinburg ("Quedlimbourg"), in Prussia. The type specimens of the second species, *O. rhaphiodon*, were obtained from the Upper Chalk of Lewes.

Genus *Otodus*, Agassiz.

Otodus is another genus founded by Agassiz upon teeth very similar to those of *Lamna*. It has no living representatives, and the teeth are recognized by (i) the much compressed form of the crown, (ii) the considerable size of the pair of lateral denticles, and (iii) the shortness of the root, which is only slightly branched.

---

[*] L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 280, Pl. xxxiii, Figs. 1-9.

[†] L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 292, Pl. xxxvii*a*, Figs. 54-57. F. Dixon, 'Foss. Suss.,' Pl. xxx, Figs. 19, 26 (?), 34.

[‡] F. Dixon, 'Foss. Suss.,' p 367, Pl. xxxi, Fig. 13.

[§] L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 296, Pl. xxxvii*a*, Figs. 5-7.

[‖] L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 296, Pl. xxxvii*a*, Figs. 11-16. F. Dixon, 'Foss. Suss.,' Pl. xxx, Fig. 32.

A single well-defined species, *O. appendiculatus*,* occurs both in the Chalk and the earlier Cretaceous deposits, and is very widely distributed, numerous examples being known both from England, the European Continent, and the United States. The teeth are especially stout, and the root much depressed; and there is considerable variation in size and shape, as shown by Agassiz's figures, and proved by the remains of nearly complete jaws in the British Museum. Larger and still more robust teeth from the English Chalk may be identified with the specimens from the Continental Greensand described by Agassiz as *O. crassus*;† and Mr. William Davies has determined one tooth from the Chalk of Rochester which agrees with Münster's *O. semiplicatus*,‡ of the Quedlinburg Chalk. The latter is large, and has the inferior margin of the outer face of the crown marked with small but strong vertical ridges.

Genus *Corax*, Agassiz.

Some small compressed triangular teeth, with delicately serrated margins, and short, slightly-branched root, are very suggestive, at first sight, of the occurrence in the Chalk of allies of the Blue Sharks (*Carcharias*) and Topes (*Galeus*). These teeth, however, when completely developed, are solid, whereas those of the genera of *Carchariidæ* just mentioned have a central cavity §; and they were thus regarded by Agassiz as generically distinct, receiving the name of *Corax*, and being placed with the other solid-toothed sharks in the family of *Lamnidæ*. The teeth vary much in form according to their original position in the jaw, some being almost symmetrical, but the majority with the apex of the crown directed backwards. The marginal serrations are mostly distinct, and always quite regular; but they are sometimes absent in the smaller teeth, which seem to have belonged to young individuals.‖ Two, or possibly three, species occur in the English Chalk, two larger (*C. pristodontus*¶ and *C. maximus***) and a smaller (*C. falcatus**). *C. pristodontus* is met with in the higher horizons, and was originally founded upon specimens from the well-known Maastricht Beds of Holland. The teeth are recognized by the great relative size of the root, and the bulging anterior margin of the crown. *C. falcatus* has a much narrower root, and the anterior margin of the crown only slightly curved ; and, in small (? mostly young) examples there are also indistinctly marked broad lateral denticles.† The teeth of Dixon's *C. maximus*, from the Chalk of Lewes, are very similar in form to those of *C. falcatus*, and quite possibly belong to large individuals of this species.

---

* L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 270, Pl. xxxii, Figs. 1-25. F. Dixon, 'Foss. Suss.,' Pl. xxx, Fig. 25; Pl. xxxi, Fig. 17.

† L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 271, Pl. xxxvi, Figs. 29-31.

‡ Münster, ? MSS. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 272, Pl. xxxvi, Figs. 32, 33.

§ According to Agassiz, *op. cit.*

‖ It is interesting to note that in the young of the living *Carcharias* the margins of the teeth are not serrated. A. Günther, 'Cat. Fishes Brit. Mus.,' Vol. viii, 1870, p. 357.

¶ L. Agassiz, 'Poiss. Foss.," Vol. iii, p. 224, Pl. xxvi, Figs. 9-13.

** F. Dixon, 'Foss. Suss.,' p. 366, Pl. xxx, Fig. 17.

Genus *Scylliodus*, Agassiz.

A fossil Dog-fish—one of the family of *Scylliidæ*—appears to be indicated by some teeth and portions of the cartilaginous skeleton from the Lower Chalk of Burham and Dover. The largest of the type-specimens figured by Agassiz ‡ shows the upper and lower jaws, with portions of labial cartilages and the ceratohyals, in addition to the greater part of the pectoral arch, and a long fragment of the vertebral column. The teeth are very small, of the same type as those of *Lamna*, but mostly having the lateral denticles larger, and the root shorter and depressed. Agassiz figures one tooth (*l.c.*, Fig. 3), but many are not so broad as this, and have the lateral denticles longer and more slender. As in all the *Scylliidæ*, several rows of the teeth are simultaneously in use, and the entire dentition is much like that of the living *Scyllium*. There appear to be no dorsal spines, and the vertebral centra are short, being about twice as deep as long. The single recognized species is *Scylliodus antiquus*.

Another genus of Asterospondylic Selachians—the extinct *Strophodus*—has also been recorded from the Chalk § ; but I have discovered that the type-specimen of the single described species, *S. asper*, Agass., is truly a fragment of a Crustacean somewhat similar to *Hoploparia*.

---

* L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 226, Pl. xxvi, Fig. 14, Pl. xxvi*a*, Figs. 1-15. F. Dixon, 'Foss. Suss.,' Pl. xxx, Fig. 18.

† Some of these have been ascribed to *Sphyrna* by E. Hébert, "Tableau des Fossiles de la Craie de Meudon," 'Mem. Soc. géol. France' [2], Vol. v (1854), p. 354, Pl. xxvii, Fig. 9.

‡ Agassiz, *op. cit.*, Vol. iii, p. 377, Pl. xxxviii.

§ Agassiz, *op. cit.*, Vol. iii, p. 128*b*, Pl. x*b*, Figs. 1-3.

Selachii Tectospondyli.

Genus *Squatina*, Aldrovandi.

The "Monk-fishes" or "Angel-fishes" have not yet been recorded from the English Chalk, but a nearly perfect example has been discovered in the Senonian of Westphalia,* another at Mount Lebanon, Syria,† and several detached teeth in Bohemia.‡ In the collection of the British Museum, however, I have met with one tooth from the Upper Chalk of Norwich, and another from Brighton; and our fellow-member, Mr. James Fox, has recently presented a third from Lewes. Another tooth is figured, without name, by Dixon.§ I have also detected remains of the head of *Squatina*, with some of the dermal tubercles, from the Lower Chalk of Brighton, in the collection of Mr. Henry Willett, F.G.S., in the Brighton Museum. The latter is a comparatively satisfactory specimen, and indicates a new species, *S. Cranei.*‖ The teeth of the genus are compressed and conical, without distinct lateral denticles, and are easily recognized by a curious downward process of the crown extending over the root immediately beneath the great cone. The body is covered with exceedingly minute ridged or stellate tubercles, and towards the margin of the paired fins there are also larger round dermal plates with recurved spines. In *Squatina Cranei* the anterior lower teeth are remarkably slender, and the spinous dermal plates of unusual size.

Genus *Ptychodus*, Agassiz.

The teeth of *Ptychodus* are so well known to all collectors and readers of ordinary text-books, that any detailed description of their characters would be superfluous. Some account of their arrangement in the jaw may, however, be of interest, with a few remarks upon the probable systematic position of the fish to which they originally belonged.

---

* W. Von der Marck, "Fische der oberen Kreide Westfalens—Dritter Nachtrag," 'Palæontographica,' Vol. xxxi (1885), pp. 264-267, Pl. xxv, Figs. 1-5.

† *Squatina crassidens*, A. S. Woodw., shortly to be described in the British Museum Catalogue of Fossil Fishes.

‡ A. E. Reuss, 'Versteín. böhm. Kreideform.,' Part ii (1846), pp. 100, 101, Pl. xxi, Figs. 18-21.

§ F. Dixon, 'Foss. Suss.,' Pl. xxx, Fig. 35.

‖ Smith Woodward, "On some remains of *Squatina Cranei*, sp. nov., etc., from the Chalk of Sussex," 'Quart. Journ. Geol. Soc.,' Vol. xliv (1888), p. 144, Pl. vii, Figs. 1-6.

By Mantell,* the well-known fossils in question were at first regarded as pertaining to a Teleostean fish, somewhat similar to the living Sea-hedgehogs (*Diodon*); but Agassiz† soon afterwards recognized their true Selachian nature, and gave them the name by which they are now designated. The author of the "Poissons Fossiles" thought that the teeth were arranged in the jaws like those of the living *Cestracion*, or Port Jackson Shark—the prehensile teeth in front, and those for crushing upon the ramus at each side. He also considered (*tom. cit.*, p. 56) that certain broad ribbed fossils, discovered in the same beds as the teeth, might reasonably be determined as the dorsal fin-spines of the fish, which was thus relegated to the *Cestraciontidæ*. Owen‡ confirmed this determination by a study of the microscopical structure of the teeth, though at the same time both he and subsequent writers recognized the remarkable superficial resemblance of the fossils to the teeth of the living Ray, *Rhynchobatus*. Later researches by Prof. Cope § among Cretaceous fossil fishes in North America, proved very conclusively that the supposed dorsal spines of *Ptychodus* really pertained to the pectoral fins of a family of Teleosteans (see *Protosphyræna*); and in 1885 the present writer || was also able to announce that Agassiz had been misled by imperfect specimens in regard to the arrangement of the teeth, there being nothing in common with the *Cestraciontidæ*, but striking points of resemblance to certain Rays. Still more recently further studies have made known¶ the complete dentition of at least one species—thanks, especially, to a fine fossil in Mr. Henry Willett's collection at Brighton—and it now appears that *Ptychodus* is either referable to a family of huge Devil-fishes (*Myliobatidæ*) or to a closely allied group hitherto unrecognized.

---

* G. A. Mantell, 'Fossils of the South Downs,' 1822, p. 231.

† L. Agassiz, 'Poiss. Foss.,' Vol. iii (1839), p. 150.

‡ R. Owen, "On the Structure of Teeth," 'Brit. Assoc. Rep.,' 1838, Trans. Sect., p. 140; and 'Odontography,' pp. 57-59, Pls. xviii, xix.

§ E. D. Cope, 'Vert. Cret. Form. West,' 1875, pp. 244*a-f*.

|| Smith Woodward, "Chapters on Fossil Sharks and Rays—iv," 'Science Gossip,' Vol. xxi (1885), p. 109.

¶ Smith Woodward, "On the Dentition and Affinities of the Selachian Genus *Ptychodus*, Agassiz," 'Quart. Journ. Geol. Soc.,' Vol. xliii (1886), pp. 121-130, Pl. x.

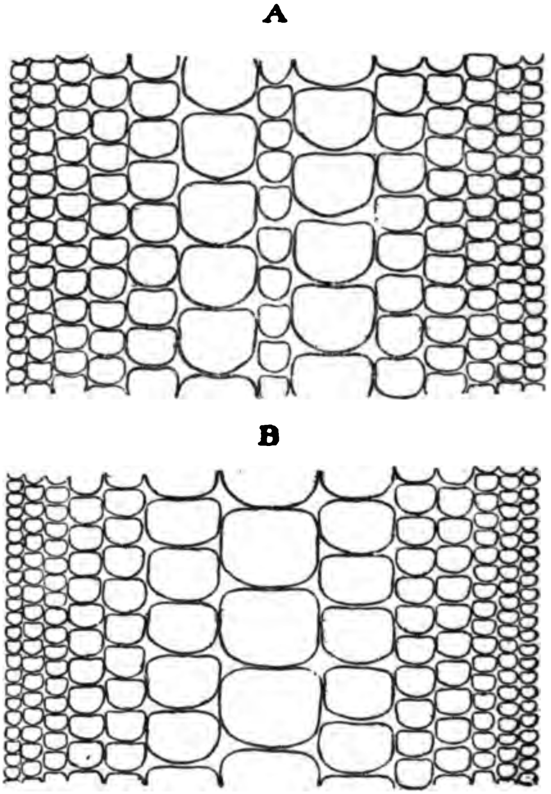


FIG. 1.—Diagram showing the arrangement of the teeth of *Ptychodus*. *A*. Upper jaw. *B*. Lower jaw.

The two halves of each jaw are placed in the same straight line, thus giving the aperture of the mouth the form of a straight transverse cleft, and the teeth are arranged in several parallel series, running directly antero-posteriorly. There is a median row in each jaw, and on either side of this there are symmetrically placed left and right series. In the upper jaw (Fig. 1, A), the median teeth are very small, and the largest are placed in the first lateral series, from which there is a gradual diminution in size outwards. In the lower jaw (Fig. 1, B), the median teeth form the largest row, fitting into the central groove of the opposing dentition, and on either side the teeth of the lateral series become successively smaller. Altogether there are thirteen of these parallel rows in the common *P. decurrens*.

From the uppermost Cretaceous rocks of Pernambuco, Brazil Prof. Cope* has described an interesting type of dentition, *Apocopodon*, which is apparently intermediate between *Ptychodus* and the living *Myliobatidæ*, and thus tends to confirm the present writer's determination already referred to. The median teeth "are shorter than in the typical forms assigned to *Myliobatis*," and "differ from the corresponding teeth of *Myliobatis* and *Zygobatis* in being exactly parallelogrammic in outline ; that is, the extremities are truncated instead of angulated as in those genera." "The lateral teeth display the usual angulation among themselves, though doubtless joined by a straight suture to the middle row." The crowns are more elevated than the roots, and separated from them by a constriction ; and the coronal surface is covered by a dense layer, marked with antero-posterior wrinkles.

Possibly of a similar type is the genus from Maastricht, represented by the detached teeth named *Rhombodus Binkhorsti*, Dames.†

It is also interesting to observe that some of the Eocene species of *Myliobatis* possess teeth remarkably similar in shape to those of *Ptychodus*. A form from the Phosphate Beds of North Carolina, described by Leidy as *Myliobatis jugosus*,‡ is especially noteworthy in this respect; and, on the whole, therefore, it seems probable that the Ptychodonts will eventually prove to be primitive types of *Myliobatidæ*.

With regard to the species of *Ptychodus*, it is impossible to make any very definite statement at present. So far as can be determined, however, from the fragmentary materials available, it appears that not less than seven forms can be distinguished in the English Chalk. Those teeth in which the median transverse folds gradually pass on either side into the granulated marginal area, are referred to *P. decurrens*.§ Comparatively high-crowned teeth, with the granulated area delicately marked and radiately channelled, are termed *P. mammillaris.*[*] The teeth of *P. rugosus* are almost like those of *P. mammillaris*, but differ in the less defined character of the surface markings, and the irregularity of the transverse ridges.[†] The teeth of *P. Oweni*[‡] have a gently rounded crown with very irregular widely-spread ridges. *P. polygyrus*[§] is the name given to very variable teeth with the larger median ridges more or less curving round at the lateral extremities and sometimes forming loops. And some large teeth with the transverse folds of enormous relative size, not more than five or six in number, are known as *P. latissimus.*[‖] The English specimens commonly referred to the American *P. Mortoni*, Mantell,[¶] are really the upper median teeth, of various other species.

---

* E. D. Cope, "A Contribution to the Vertebrate Palæontology of Brazil," 'Proc. Amer. Phil. Soc.,' Vol. xxiii (1886), p. 2.

† W. Dames, "Fischzähne aus der obersenonen Tuffkreide von Maastricht," 'Sitzungsb. Ges. Naturf. Freunde, Berlin,' 1881, pp. 1-3.

‡ J. Leidy, "Description of Vertebrate Remains chiefly from the Phosphate Beds of S. Carolina," 'Journ. Acad. Nat. Sci. Philad.' [2], Vol. viii (1877), p. 240, Pl. xxxi, Figs. 4, 5.

§ L. Agassiz, 'Poiss. Foss.,' Vol. iii, p. 154, Pl. xxv*b*, Figs. 1, 2, 4, 6-8. F. Dixon, 'Foss. Suss.,' p. 362, Pl. xxx, Figs. 7, 8; xxxi, Fig. 1 ; xxxii, Fig. 5. Also *P. depressus*, Dixon, *op. cit.*, p. 363, Pl. xxxi, Fig. 9.

Abraded teeth of *Ptychodus* are also occasionally met with, and Dixon has described two as "nascent teeth,"[**] while another flatter example forms the type of a so-called new genus and species *Aulodus Agassizi.* [††]

The centra of the vertebral column of *Ptychodus* are well calcified, and their identity is proved by a specimen of *P. decurrens* in the British Museum (No. 39,436), in which they are intimately mingled with fragments of cartilage and teeth. An almost perfect vertebra from the Upper Chalk of Dorking has been described in mistake by Dr. Carl Hasse,[‡‡] as pertaining to a Cretaceous species of *Selache*, named *S. Daviesii* (misspelt *Davisi*), in honour of Mr. William Davies, of the British Museum. In transverse section the vertebra shows four wedge-shaped hollows filled with matrix, in the form of a cross, and between these there are numerous closely-arranged conçentric laminæ, apparently not connected by any radiating plates.

---

[*] Agassiz, 'Poiss. Foss.,' Vol. iii, p. 167, Pl. xxv*b*, Figs. 12-20. Dixon, 'Foss. Suss.,' p. 361, Pl. xxx, Fig. 6; xxxi, Fig. 4.

[†] Dixon, 'Foss. Suss.,' p. 362, Pl. xxxi, Fig. 5.

[‡] Dixon, 'Foss. Suss.,' p. 364, Pl. xxxi, Fig. 2.

[§] Agassiz, 'Poiss. Foss.,' Vol. iii, p. 156, Pl. xxv, Figs. 4-11; Pl. xxv*b*, Figs. 21-23. Dixon, 'Foss. Suss.,' p. 363, Pl. xxx, Fig. 9; xxxi, Fig. 10.

[‖] Agassiz, 'Poiss. Foss.,' Vol. iii, p. 157, Pl. xxv*a*, Figs. 1-6 (not Fig. 7, which represents a lower median tooth of *P. polygyrus*), Pl. xxv*b*, Figs. 24-62. *P. paucisulcatus*, Dixon, 'Foss. Suss.,' p. 363, Pl. xxx, Fig. 3.

[¶] *e.g.*, Dixon, 'Foss. Suss.,' p. 364, Pl. xxxi, Figs. 6, 7.

[**] F. Dixon, 'Foss. Suss.,' p. 364, Pl. xxx, Figs. 4, 5.

[††] F. Dixon, 'Foss. Suss.,' p. 366, Pl. xxxii, Fig. 6.

[‡‡] C. Hasse, "Einige seltene paläontologische Funde," 'Palæontographica,' Vol. xxx 1884), p. 9, Pl. ii, Figs. 16, 17.

Order CHIMÆROIDEI.

The Chimæroid fishes are represented in the English Chalk by the teeth and dorsal fin-spines of three extinct genera, *Edaphodon*, *Ischyodus*, and *Elasmodectes* (= *Elasmognathus*, E. T. Newton). They are cartilaginous fishes with the vertebral column consisting merely of slender calcified rings, and commonly classed with the Sharks and Rays. From the latter, however, they differ fundamentally in having the upper jaw (palato-pterygo-quadrate cartilage) fused with the skull, and the gill-clefts are also covered with a fold of skin, so that it is convenient to regard them as a distinct order. The teeth are very remarkable, and easily recognized when once seen. Each consists of a mass of bony matter surrounding isolated patches, or "tritoral areas" of harder white dentine, covered with punctures (the openings of vascular canals). Beneath each functional grinding plate is a pillar of similar material, which grows gradually upwards to replace the topmost layer, as it is worn away by trituration. One of the teeth occupies each half of the lower jaw, meeting its fellow at the symphysis in front; it is of triangular shape, laterally compressed, with the anterior angle produced more or less into a beak, and the "tritors" are placed either along the cutting edge, or both in this position and upon the inner side. In the upper jaw there are two teeth on each side meeting in the middle line, and these correspond to the so-called palatine and vomerine teeth of the Dipnoan *Ceratodus*. The hinder pair are the largest, triangular in shape, and readily distinguished from the mandibular teeth in the commonest Chalk genera, by the fact of their not being laterally compressed, but having a flat, grinding surface with tritors, and meeting one another in the median line throughout their entire length. The fore-pair of median teeth are short, triangular, laterally compressed, and curved to meet each other in front, producing a kind of beak, with tritors only upon the cutting edge. Sometimes these teeth are spoken of respectively as mandibles, maxillæ, and premaxillæ, the tritoral areas being then termed teeth; but, though convenient, this nomenclature can scarcely be justified by the obvious homologies of the parts.

The spine in front of the dorsal fin, in most Chimæroids, is long, slender, laterally compressed, and marked on the sides with coarse longitudinal striæ. There are two rows of small, recurved denticles on the hinder border, and the lower extremity is articulated with a large cartilage. Such detached fossil spines have been described by Agassiz from several formations under the name of *Leptacanthus.*

Genus *Edaphodon*, Buckland.

To the genus *Edaphodon* may be referred most of the Chimæroid fossils of the Chalk; and for detailed descriptions and figures both of these and other known forms, reference may be made to Mr. E. T. Newton's exhaustive Memoir on "The Chimæroid Fishes of the British Cretaceous Rocks," published by the Geological Survey in 1878. The mandibular tooth is recognized by the great width of the flat "symphysial" surface in front, by which it unites with its fellow of the opposite side, and by the absence of any outer bony thickening of the upper margin. There is one beak-tritor, and posteriorly, on the inner side, are two small tritors just beneath the upper margin, with a single larger one, sometimes longitudinally divided, below. The hinder upper tooth shows two inner tritors and one outer; and the anterior upper tooth is not readily distinguished from that of *Ischyodus,* though perhaps less robust. Seven Cretaceous species are recognized by Mr. Newton, five of these occurring in the Chalk itself. Of *E. Sedgwickii*, first founded upon a mandibular tooth from the Cambridge Greensand, the complete dentition has been found associated in the Chalk of Lewes. *E. Agassizii* occurs in the Chalk Marl and Lower Chalk, and one specimen in the British Museum shows the dorsal spine in association with the mandibular teeth. *E. Mantelli* ranges throughout the Upper and Lower Chalk and the Chalk Marl. *E. gigas* appears to be obtained from the Upper Chalk, and *E. crassus* from the Lower.

Genus *Ischyodus*, Egerton.

The teeth of *Ischyodus* are usually distinguished at once by a curious bony layer upon the outer aspect, that of the mandibular tooth forming a well-marked thickening of the upper border. The lower tooth also differs from that of *Edaphodon* in being ordinarily more slender, and in having the "symphysial surface" narrow, with a longitudinal ridge and groove. In the hinder upper tooth there are four tritors, instead of three, as in *Edaphodon*, a median one being placed between the inner and the outer. A variety of the common Gault species, *Ischyodus brevirostris,* is believed to occur in the Lower Chalk; and Mr. Newton founds a new species, *I. incisus*, upon a small, thin mandibular tooth from the same horizon.

Genus *Elasmodectes* (*Elasmognathus*, Newton).

A small Chimæroid mandibular tooth from the Lower Chalk of Southeram, Sussex, preserved in Mr. Willett's collection, is remarkable from the circumstance that it is adapted for cutting rather than crushing, like the mandibular tooth of the living *Chimæra*. As this type is evidently generically distinct, it has been described by Mr. E. T. Newton under the name of *Elasmognathus*,* in reference to the thin plate-like form of the tooth; and the single recognized species is known as *E. Willettii*. The inner side of each dental plate is marked by parallel lines of growth, giving it a wavy appearance, and there are no downwardly-extending broad tritoral surfaces, like those of *Edaphodon* and *Ischyodus*. The outer side shows no thickening of the upper border, and this is wavy, exhibiting three peaks, the first at the symphysis, joining with its fellow of the opposite side to form the anterior beak. The fossil appears to be extremely rare, having only been met with in the Lower Chalk of Southeram, Sussex, and Burham, Kent. The upper teeth still remain undiscovered.

Order GANOIDEI.

The Ganoid fishes of the Chalk, so far as recognizable, are few. It is, however, impossible to determine how many of the genera, commonly placed under the physostomous Teleosteans, might fall under this denomination, if only we were acquainted with the characters of their soft parts. The Ganoids differ from the Teleostei in not having the optic nerves decussating, and in possessing a spiral valve in the intestine, and a contractile conus arteriosus in connection with the heart. The later members of the order cannot be definitely separated from the more primitive Teleosteans by skeletal characters alone; and so many intermediate conditions in regard to the soft parts have also been discovered among living fishes within recent years, that the convenience of retaining this long-adopted division becomes questionable. Prof.

---

* As pointed out to me by Mr. Lydekker, this generic name was preoccupied, having been employed by Dr. J. E. Gray, in 1867, for a Tapir. With little change of significance, the name of *Elasmodectes* (blade-biter) may be substituted.

Cope * has proposed a rearrangement especially worthy of consideration.

Crossopterygian (Fringe-finned) Ganoids.

Genus *Macropoma*, Agassiz.

A single representative of the Fringe-finned Ganoids occurs in the Chalk—the genus *Macropoma*, referable to the ancient, and now extinct, family of *Cœlacanthidæ*, founded by Agassiz † and amended by Huxley. ‡ Like the earlier genera of the same family, *Cœlacanthus*, *Holophagus*, &c., it is a robust fish, with large head, two short dorsal fins, one anal, and a remarkable, large caudal fin, supported by interspinous bones both above and below; it also probably possessed a small supplementary caudal, but this has not yet been discovered. The roof of the skull is sharply bent above the orbit, the front portion being thus very steep, and the constituent bones are externally pitted; the outer jaw-bones and the opercular bones are ornamented with shining tubercles, and there is a pair of similarly marked gular plates between the rami of the mandible, replacing branchiostegal rays. The teeth are small, curved, and conical, most powerful in front, and those of the upper jaw are fixed at least upon the maxillæ, palatines, and (?) vomers. The notochord must have been persistent, there being no traces of vertebral centra in the fossils; and there are no ribs. A great ossified air-bladder, first recognized by Mantell, § and mistaken by Agassiz for the stomach, is generally seen in the abdominal cavity of the fish. The scales are thin and cycloid, considerably overlapping, and the exposed portion is of rhombic shape, ornamented with "elongated splashes and dots of enamel." The fin-rays of the dorsal, anal, and caudal fins are neither jointed nor branching, and each is provided with a double anterior series of sharp spinelets, having the points all directed towards the distal end of the ray.

---

* E. D. Cope, "Observations on the Systematic Relations of the Fishes," 'Proc. Amer. Assoc. Adv. Sci.,' Vol. xx (1871), pp. 317-343. See also 'Proc. Amer. Phil. Soc.,' Vol. xvii (1878), p. 41, and *ibid.*, Vol. xxi (1884), pp. 577-579.

† L. Agassiz. 'Poiss. Foss.,' Vol. ii, Pt. ii, p. 168.

‡ T. H. Huxley, "Illustrations of the Structure of the Crossopterygian Ganoids—Figs. Brit. Org. Remains," Dec. xii ('Mem. Geol. Sur.'), 1866.

§ G. A. Mantell, 'Foss. South Downs,' 1822, p. 239. The structure of this air-bladder has been described by W. C. Williamson, "On the Microscopic Structure of the Scales and Dermal Teeth of some Ganoid and Placoid Fishes," 'Phil. Trans.,' 1849, p. 463, Pl. xliii, Figs. 29, 30.

Only a single species, *M. Mantelli,** is known from the English Chalk, but Reuss† and Fritsch‡ have determined others from Bohemia. Prof. Huxley's *M. substriolatum,* from the Kimmeridge Clay of Cottenham, is believed by Zittel§ and Reis to be generically distinct, and referable to *Coccoderma,* Quenstedt; while the so-called *M. Egertoni,* Agass.,|| from the Gault of Speeton, is really not referable to the Cœlacanth family.

The coprolites of *Macropoma* show the impressions of the spiral valve of the intestine, and were originally regarded as fossil fir-cones.¶

Actinopteran (*Ray-finned*) *Ganoids.*

Genus *Lophiostomus,* Egerton.

This is a ganoid fish of uncertain position, with a thick depressed head and body, enormous mouth, and an impenetrable armour of rhomboidal enamelled scales. A single species only has been described—*L. Dixoni,* Egerton,** from the Chalk of Alfriston, Sussex; and the type specimen, which shows the head, portions of pectoral and pelvic fins, and a few scales, is preserved in the British Museum. The head bones and the rays of the fins are ornamented with irregular tubercles of ganoine; and the margin of the jaw is provided, above and below, with a "single series of long, sharp, conical teeth, very regular in size, incurved at the points, and fluted on the surface." Smaller teeth of a similar type are also found in an inner row parallel to the outer, those of the upper jaw being probably situated upon the vomers and palatines. The scales are rhomboidal and covered with a thick layer of shining ganoine, which is irregularly pitted, and they may be readily

---

* L. Agassiz, 'Poiss. Foss.,' Vol. ii, Pt. ii, pp. 174-177, Pl. lxva-*d*. T. H. Huxley, *op. cit.*, pp. 27-39, Pls. vii, viii. This species being originally named *Amia? lewesiensis*, by Mantell (*op. cit.*, p. 239), it ought strictly to be termed *Macropoma lewesiensis;* but in memory of Dr. Mantell, it seems preferable to adopt the widely accepted name.

† A. E. Reuss, "Neue Fischreste aus dem böhmischen Pläner," 'Denkschr. math.-naturw. Cl. k. Akad. Wiss. Wien,' Vol. xiii (1857), pp. 33-39, Pls. i, ii.

‡ A. Fritsch, 'Reptilien und Fische der böhmischen Kreideformation,' 1878, pp. 26-31, Pl. iii, Pl. iv, Figs. 2-7.

§ K. A. Zittel, 'Handb. Palæont.,' Vol. iii (1887), p. 176.

|| Described by Egerton, "Figs. and Descr. Brit. Org. Remains," Dec. ix ('Mem. Geol. Surv.,' 1857), Pl. x.

¶ See J. Parkinson, 'Organic Remains of a Former World,' Vol. i (1820), p. 447, Pl. vi, Figs. xv, xvii.

** Sir P. Egerton, "Figs. and Descriptions of British Organic Remains," Dec. vi ('Mem. Geol. Surv.,' 1852), Pls. x, x.*

recognized by the comb-like serrated posterior margin ; they have been met with in the Chalk of several English localities.

Genus non det.

Lophiostomus is not the only rhombic-scaled ganoid of which the English Chalk yields evidence. Agassiz* has already recorded (not described) some thick enamelled scales, slightly punctated, with apparently smooth posterior border, under the name of *Lepidotus punctatus;* though a specimen in the British Museum (No. P. 4705) shows that this generic determination is incorrect, the scales of the ventral aspect of the fish being much more elongated than those of the flank, as in the Jurassic *Eugnathus.* Some of these scales, from the collection of Mr. S. J. Hawkins, F.G.S., are shown in Pl. I, Fig. 2, and it seems advisable at present to leave them generically undetermined.

Genus *Neorhombolepis*, A. S. Woodw.

Another fossil in the British Museum (No. 43,077) indicates a third genus of rhombic-scaled ganoids in the Chalk. It is shown, of the natural size, in Pl. I, Fig. 1.

This specimen, though too imperfect to allow of precise generic diagnosis, belongs to an interesting novel type, and, as a matter of convenience, I propose to adopt the usual palæontological expedient of applying to it a distinct name—that of *Neorhombolepis excelsus* —until the genus and species can be scientifically defined. The fossil was obtained from the Lower Chalk of Halling, Kent. It shows the opercular bones, postclaviculars, the right pectoral fin, numerous rows of ventral scales, and a portion of the vertebral column. The operculum is almost quadrate, and the suboperculum is relatively large, having about two-thirds the vertical extent of that bone. The postclavicular scales are four in number, and very similar to those of *Lepidotus*, *Dapedius*, and their allies ; and they are externally ornamented with fine rugose markings, as also, probably, would be the opercular elements if their outer surface were well preserved. The pectoral fin consists of thirteen powerful rays, the first being especially robust; and all are undivided for the greater portion of their length, though closely articulated distally. The scales of the ventral aspect are very much elongated, being often nearly three times as long as deep, but those of the upper part of the flanks might possibly be deeper, as in other genera with a similar ventral squamation. These scales are enamelled and quite smooth, and some have posterior serrations; but they are not united by peg-and-socket joints. The vertebral column differs from that of all other genera with which the external characters of the fish would suggest comparison, in being completely ossified; and the vertebral centra are biconcave and relatively short.

---

* L. Agassiz, 'Poiss. Foss.,' Vol. ii., Pt. i, p. 306. A portion of a fish named *Lepidotus striatus* is also described and figured from the Chalk of Normandy, *tom. cit.*, p. 268, Pl. xxxiva, Fig. 4. H. E. Sauvage has since referred other detached scales, from the French Chalk, to *Lepidotus* ('Recherches sur les Poissons Fossiles du Terrain Crétacé de la Sarthe,' "Bibl. l'École Hautes Etudes," Vol. v, No. 9 (1872), pp. 4-6, Figs. 20-24).

The operculum of the specimen just described measures about 25 millim. vertically, and 25 millim. anteroposteriorly; the unjointed portion of the first ray of the pectoral fin is 40 millim. in length; an anterior ventral scale measures 4 millim. by 1·5 millim.; and each vertebral centrum has a depth of about 8 millim. and a length of 4·5 millim.

Genus *Belonostomus*, Agassiz.

This is a long-bodied fish, with strong enamelled ganoid scales, and is typically a Jurassic genus, though rarely represented by a single species, *B. cinctus*, Agass.*—and perhaps by a second, *B. attenuatus*, Dixon†—in the English Chalk. The scales of the middle of the flank are much vertically elongated, while those placed dorsally and ventrally are relatively short; all being smooth and destitute of posterior serrations. The snout is enormously elongated, and the lower jaw is almost of equal length. The latter is the most interesting part of the fish hitherto discovered, and I have lately been able to elucidate (*loc. cit.*) some of its characters by an examination of two of Mr. Willett's fine fossils from Brighton. Its great length is not due to the elongation of the halves of the jaw proper, but to the presence of an unpaired element in front (the "pre-symphysial bone") which has an extent equal to that of the whole of the ordinary mandibular bones themselves. This curious bone tapers in front and is provided with a median row of very large, hollow, conical teeth, at distant intervals, flanked on either side by very minute conical teeth. The rami of the jaw behind are provided with clustered, mammillated, crushing teeth, perhaps fixed upon the "splenial" bone. The latter have not previously been discovered, and the tooth-bearing fragments described by Agassiz are pieces of the presymphysial bone.

---

* L. Agassiz, 'Poiss. Foss.,' Vol. ii, Pt. ii, p. 142, Pl. lxvia, Figs. 10-13. F. Dixon, 'Foss. Suss.,' p. 367, Pl. xxxv, Figs. 3, 3.* Smith Woodward, "On a Mandible of *Belonostomus cinctus* from the Chalk of Sussex," 'Quart. Journ. Geol. Soc.,' Vol. xliv (1888), p. 145, Pl. vii, Figs. 7-13.

† F. Dixon, 'Foss. Suss.,' p. 368, Pl. xxxv, Figs. 4, 4.*

The latter bone is also present and dentigerous in the closely allied genus *Aspidorhynchus*, though here it is comparatively small. Its true characters in the Jurassic *Belonostomus* were first pointed out by Otto Reis.*

Genus *Prionolepis*, Egerton.

Some naturally associated ganoid scales from the Chalk of Burwell, near Newmarket, were figured in Dixon's 'Foss. Suss.' (Pl. xxxii*, Fig. 3), and briefly described by Sir Philip Egerton (*op. cit.*, p. 368), under the name of *Prionolepis angustus;* but nothing more has subsequently been discovered in regard to the essential characters of the fish. Sir Philip Egerton compared it with the long-bodied *Aspidorhynchus*, and it is perhaps most nearly allied to the family comprising the latter. The scales of the side of the trunk are much elongated vertically, being sometimes six times as deep as broad; and these are pierced at a distance of about one-third of the total depth from the upper end by the canal of the "lateral line." Above this, which produces a small transverse ridge, the scale is bent obliquely forwards, and below it curves still more gradually backwards, terminating in a somewhat rounded lower extremity. The posterior border, both of this scale and of the much shorter ones, which are placed dorsally and ventrally, has a comb-like appearance, being strongly denticulated; and the remainder of the external surface of the scale is either smooth or ornamented with very fine vermiculations.

The type specimen is now preserved in the British Museum, and there are also less perfect examples from the Lower Chalk of Dover, and the Upper Chalk of Dorking, Surrey, and Swaffham, Norfolk.

(?) Genus *Caturus*, Agassiz.

A fragment of jaw from the Chalk of Kent was referred by Agassiz† to the well-known Upper Jurassic genus *Caturus*, but no subsequent discoveries have tended to confirm this determination, which is thus extremely doubtful. The fossil shows a series of widely spaced laterally compressed teeth fixed in sockets, and almost of uniform size, and it is not improbably referable to an unknown Teleostean. It bears the specific name of *similis*.

---

* O. Reis, "Ueber *Belonostomus*, *Aspidorhynchus*, und ihre Beziehungen zum lebenden *Lepidosteus*," Sitzungsb. math-phys. Cl. k. bay. Akad. Wiss. München, 1887, p. 169, Pl. i, Fig. 4.

† Agassiz, 'Poiss. Foss.,' Vol. ii, Pt. ii, p. 118, Pl. lxvi*a*, Fig. 9.

Genus *Cœlodus*, Heckel.

Though the specimens are too imperfect to allow of certain determination, the majority of the known Pycnodont remains from the Chalk seem to pertain to *Cœlodus*[*] as already pointed out by Zittel.[†] In this genus the unworn teeth are hollowed in the middle of the summit of the crown (as denoted by the name), and the more elongated examples are also raised at either extremity. Each half of the lower jaw is provided with three series, the innermost being much the largest; and the teeth both of this and the second row are greatly transversely elongated, while in the outermost series they are small and round. In the upper jaw the median teeth are oval and transversely elongated to a slight extent; and these are flanked on either side by two rows of smaller oval teeth, the long axes placed in an antero-posterior direction.

The finest Pycnodont fossils hitherto described from the English Chalk are those from Houghton, Sussex, made known by Dixon,[‡] and referred to Agassiz's *Gyrodus angustus* (now to be termed *Cœlodus angustus*). One large specimen shows both mandibular rami, with the dentition, and some well-preserved scales, with the interspinous bones of the anal fin; and in another is preserved a portion of the axial skeleton with neural spines and ribs. The scales cover the anterior half of the trunk, having the usual form, and they are comparatively thick, with a pitted ornamentation. The ventral comb-like ridge-scales in the first specimen are erroneously described by Dixon as pertaining to "the nape of the neck." The lower dentition is not precisely of the ordinary *Cœlodus*-type, nor yet quite like *Gyrodus*; there being one principal row of laterally elongated teeth, each with a median longitudinal depression soon obliterated by wear, and, on either side of this, small elongate teeth, with a deeper median hollow, irregularly arranged in series. Flanking these again are a number of very small teeth almost round and pitted at the summit. *Cœlodus cretaceus*, referred to *Pycnodus* by Agassiz,* is founded upon the mandibular dentition in the British Museum from the Lower Chalk of Halling, Kent. *Cœlodus parallelus*, referred by Dixon† to *Pycnodus*, is somewhat similar, but having the lower teeth more laterally elongated.

---

[*] J. J. Heckel, 'Beiträge zur Kenntniss der fossilen Fische Oesterreichs,' Pt. i, 1849, p. 202, Pl. i, Fig. 6.

[†] K. A. Zittel, 'Handb. Palæont.,' Vol. iii, 1887, p. 245.

[‡] F. Dixon, 'Foss. Suss.,' p. 370, Pl. xxx, Fig. 14; Pl. xxxiii, Fig. 1.

Acrotemnus faba, Agassiz,‡ may also probably be placed here, and is very imperfectly defined, being only known from an unique fossil in the British Museum displaying a few detached teeth. *Phacodus punctatus*, Dixon,§ must further be dismissed as founded upon six much abraded teeth, in natural association, which are quite indeterminable.

Genus *Gyrodus*, Agassiz.

The detached vomerine dentition of a species of *Gyrodus* (*G. cretaceus*) from the Chalk of Lewes was described by Agassiz,‖ and another example was subsequently figured by Dixon.¶ The crowns of the teeth are round or oval, comparatively high, coarsely rugose, and mostly hollowed at the summit. Between the large median series and the pair of lateral rows there are numerous teeth of smaller sizes placed irregularly. The lower dentition is still unknown, and, upon present evidence, Dixon's *G. conicus*** must be regarded as founded upon unworn teeth of this species.

(?) Genus *Microdon*, Agassiz.

Though recorded by Dixon,†† the genus *Microdon* is not certainly represented in the Chalk. I have already shown that "*Microdon nuchalis*" is truly a Teleostean fish,‡‡ and the fragment of the anterior portion of a Pycnodont described as *M. occipitalis* does not appear to be generically determinable.

Order TELEOSTEI.

Detached scales and teeth of Bony Fishes, or Teleostei, are abundant in the Chalk, and the accumulated discoveries of many years have also furnished the palæontologist with numerous tolerably perfect individuals by which the precise characters of several genera and species can now be determined. The majority of the forms seem to belong to the more primitive or *physostomous* division of the order, in which the air-bladder is connected with the gullet throughout life, and may perhaps in some cases have as much connection with respiratory functions as it is said to possess in the living Ganoids, *Amia* and *Lepidosteus*. Few of the Cretaceous fossils, however, can be definitely placed in still existing families. The Herrings and Salmon-tribe are apparently represented, but there are other types quite unknown in present seas. Of higher fishes —the *physoclysti*, or those in which the air-bladder of the adult is not connected by a duct with the alimentary tract—the English Chalk yields several types, though mostly referable to the less specialized groups. The grey mullets (*Mugilidæ*), with abdominal pelvic fins, seem to have representatives, and so also the Berycoid fishes, in which the pelvic fins are placed far forwards (being "thoracic"), but yet retain as many as seven or eight soft rays in addition to the spine. The majority of the spiny physoclystous fishes at the present day have the pelvic fins reduced to five soft rays at the most.

---

* L. Agassiz, 'Poiss. Foss.,' Vol. ii, Pt. ii, p. 198, Pl. lxxii*a*, Fig. 60.

† F. Dixon, 'Foss. Suss.,' p. 369, Pl. xxxiii, Fig. 3.

‡ L. Agassiz. 'Poiss. Foss.,' Vol. ii, Pt. ii, p. 203, Pl. lxvi*a*, Figs. 16-18.

§ F. Dixon, 'Foss. Suss.,' p. 371, Pl. xxx, Fig. 16.

‖ L. Agassiz, 'Poiss. Foss.,' Vol. ii, Pt. ii, p. 233, Pl. lxix*a*, Fig. 13.

¶ F. Dixon, 'Foss. Suss.,' p. 370, Pl. xxx, Fig. 15.

** F. Dixon, 'Foss. Suss.,' p. 370, Pl. xxxii, Fig. 8.

†† F. Dixon, 'Foss. Suss.,' p. 369, Pl. xxxii, Fig. 7; Pl. xxxii*, Fig. 2.

‡‡ See p. 326, *infra*.

Physostomous Teleosteans.

These are generally characterized by the margin of the upper jaw being formed both by the maxilla and premaxilla, and by the absence of spinous rays in the pelvic pair of fins, which have an abdominal situation. Some of the Chalk fossils, however, referred to this division, are exceptional in possessing pelvic fin-spines, and certain other unusual features in the skull, and much yet remains to be learned as to their true systematic relationships.

These Cretaceous fishes, indeed, are not, as yet, very satisfactorily divided into families, though Prof. E. D. Cope has made valuable contributions to the subject. So far as I have had the opportunity of studying the specimens they seem to fall under at least five or six groups as follows :—

I. Laterally-compressed fishes with large and powerful maxillæ and premaxillæ, bearing teeth, the dentary being the only tooth-bearing bone of the lower jaw, provided with a single series, the palatine and ectopterygoid toothless The teeth are placed in complete sockets. Vertebræ, except near the head, deeply two-grooved on each side in addition to possessing pits for insertion of neural and hæmal arches. Ex.: *Portheus, Ichthyodectes, Daptinus, Saurocephalus.* (Forming the family *Saurodontidæ* of Cope.)

II. Fishes somewhat less laterally compressed, provided with scales or bony scutes, or both, and having the premaxillæ and maxillæ large, bearing powerful teeth in one or more series. The dentary bone of the lower jaw similarly dentigerous. The teeth not implanted in complete sockets, but anchylosed to the jaw-bones. Abdominal vertebræ, at least, without deep lateral pits, but longitudinally striated. Ex.: *Pachyrhizodus, Empo,* (?) *Stratodus.*

III. Fishes only moderately compressed from side to side, naked, or provided with scutes. Both maxilla and premaxilla long and slender, the former about half-excluded from the margin of the upper jaw by the latter; the maxillary and premaxillary teeth small. Palatines and ectopterygoids powerful, and bearing a single series of large teeth, upon expanded bases, anchylosed to the bone. Dentary bone of lower jaw with one series of large teeth, and one or more series of small teeth, similarly anchylosed. Vertebræ with two deep lateral impressions and pits for the neural and hæmal arches. Ex.: *Enchodus, Eurygnathus,** *Eurypholis, Ischyrocephalus, Cimolichthys, Pomognathus.*

IV. Elongated fishes, with powerful dentition, and the trunk armed with several longitudinal series of bony scutes; not yet precisely defined and separated from groups II. and III. Ex. *Dercetis* (*Leptotrachelus*), *Pelargorhynchus, Plinthophorus.*

V. The *Protosphyrænidæ* (= *Erisichtheidæ,* Cope), with much elongated snout (ethmoid bone), and long maxilla loosely connected with the premaxilla; also believed to have an unusually complex mandible. Ex.: *Protosphyræna.*

VI. Clupeoids and Salmonoids.

Genus *Portheus,* Cope.

Among the type-specimens of a so-called genus, *Hypsodon,* Agassiz unfortunately mingled the remains of two distinct genera. This circumstance was first recognized by Prof. Cope,† who eliminated the one form under the generic name of *Portheus,* and left the other for further investigation. A few years later, Mr. E. T.

---

* J. W. Davis, "Foss. Fishes Mt. Lebanon," 'Trans. Roy. Dublin Soc.' [2], Vol. iii, 1887, p. 601. The name *Eurygnathus* had previously been employed for a beetle (Wollaston, 'Insecta Mader.,' 1853, p. 20).

† E. D. Cope, 'Vert. Cret. Form. West,' 1875, p. 189.

Newton[*] confirmed Prof. Cope's determination, describing certain of the English fossils as *Portheus Mantelli*,[†] and referring another[‡] to an uncertain species of the same genus ; while he corrected and supplemented Agassiz's description of the other specimens,[§] which he considered might still retain the old name of *Hypsodon levesiensis*, and be regarded as the types thereof. The latter I have since discovered to be identical with Dixon's *Pachyrhizodus*, and, as both Agassiz's original description and figure are quite misleading, it is thus convenient to expunge the ill-defined term, *Hypsodon*, entirely from the nomenclature of the group.

The teeth of *Portheus* are of unequal sizes, cylindrical or flattened, without cutting edges, and placed in a single row upon the margin of the jaw. The teeth upon the premaxilla, the anterior portion of the maxilla, and in front of the mandible, are much larger than the others. The cranial bones are not sculptured, and the entire skull is made known by Prof. Cope (*loc. cit.*) and Mr. E. T. Newton.[‖] There is at least one powerful smooth spine in advance both of the pectoral and pelvic fins.

The large English species, *P. Mantelli*, is founded upon the specimens figured and described in Mantell's 'Foss. South Downs,' p. 241, Pl. xlii, as pertaining to an "Unknown Fish," and subsequently referred by Agassiz to *Hypsodon*. Another species is *P. Daviesii*,[¶] founded upon a maxilla and associated vertebra from the Lower Chalk, probably of Maidstone ; and there appears to be less certain evidence of still more.

Genus *Ichthyodectes*, Cope.

The known remains of *Ichthyodectes* are less perfect than those of the preceding genus, and the dentition appears to differ but little except in its uniformity. The teeth are nearly of equal size, and the genus was originally founded upon American fossils.[**] A portion of the mandible of one species (*I. minor*) from the Sussex

---

[*] E. Tulley Newton, "On the Remains of *Hypsodon*, *Portheus*, and *Ichthyodectes*, from British Cretaceous Strata, with Descriptions of new Species," 'Quart. Journ. Geol. Soc.,' Vol. xxxiii (1877), pp. 505-510.

[†] *Unknown Fish*, Mantell, 'Foss. South Downs,' 1822, p. 241, Pl. xlii. *Hypsodon lewesiensis*, Agassiz, 'Poiss. Foss.,' Vol. v, Pl. xxv*b*, Figs. 1, 2.

[‡] *Hypsodon lewesiensis*, Agassiz, 'Poiss. Foss.,' Vol. v, Pl. xxv*b*, Fig. 3.

[§] *Hypsodon lewesiensis*, Agassiz, 'Poiss. Foss.,' Vol. v, p. 99, Pl. xxv*a*, Figs. 1, 2, 4, Pl. xxv*b*, Figs. 4, 5.

[‖] *Portheus gaultinus*, Newton, *loc. cit.*, pp. 512-520, Pl. xxii, Figs. 1-12.

[¶] E. Tulley Newton, *loc. cit.*, p. 511, Pl. xxii, Fig. 13.

[**] E. D. Cope, "On the Saurodontidæ," 'Proc. Amer. Phil. Soc.,' Vol. xi, (1871), p. 536. Also E. D. Cope, 'Vert. Cret. Form. West.,' 1875, p. 205.

Chalk was figured by Dixon under the name of *Hypsodon minor*;* and Mr. E. T. Newton has discovered another form in the Lower Chalk of Dorking, with more delicate obliquely-implanted teeth, appropriately named *I. elegans*.†

Genus *Daptinus*, Cope.

To this genus Mr. E. T. Newton has referred a remarkably perfect head, with the opercular apparatus and anterior vertebræ, from the Lower Chalk of Dover.‡ The specimen, which is preserved in the British Museum, is apparently intermediate between the American fossils placed by Cope in the genera *Daptinus* and *Ichthyodectes*, and is therefore appropriately named *D. intermedius*. The bones exhibit no superficial ornamentation, and the outlines of the more prominent elements are described in detail. The teeth are smooth, laterally compressed cones, with sharp edges; and they have long, hollow roots, sunk as usual in deep sockets, being replaced vertically. The mandible is relatively long and slender; the premaxilla is short and deep; and the maxilla is also comparatively short, being deepest in front, where it joins the premaxilla and appears to articulate with the palatine. The opercular bones are very large, and the operculum itself is roughly quadrilateral. The vertebræ are completely ossified, and there is an elongated lateral pit upon the centrum between the rib and the neural arch; the basal halves of the latter seem to have been lodged in a pair of deep depressions in the centrum, and so likewise the small ossicles supporting the ribs.

Genus *Tomognathus*, Dixon.

The skull and mandible are the only parts of *Tomognathus* at present known,§ and these have not yet been described in detail, The skull is considerably deeper than broad, with a large orbit; and the bones are not externally ornamented. The upper jaw is formed both by the maxilla and the premaxilla. The premaxilla is short and deep, with an upwardly directed process, and bears three or four very large teeth; the maxilla is long and slender, gradually becoming deeper behind, and the teeth are much smaller than those of the premaxilla, rapidly decreasing in size backwards. The mandible is long, and the anterior half is tooth-bearing and narrow, though soon becoming relatively very deep posteriorly, by a characteristic upward curve of the superior border; as in the upper jaw, the dentary teeth are much the largest in front, and inside these is a series of very small teeth, probably fixed upon the splenial bone. All the teeth are nearly cylindrical, pointed, enamelled in the distal half, and apparently anchylosed to the jaw, without sockets; and the enamelled portion of each of the larger ones is also longitudinally ridged and grooved. The typical species is *T. mordax*, Dixon; and *T. leiodus*, Dixon, is very doubtfully distinct.

---

* F. Dixon, 'Foss. Suss.,' p. xiv, Pl. xxxii,* Fig. 9.

† E. Tulley Newton, *loc. cit.*, p. 521, Pl. xxii, Fig. 15.

‡ E. T. Newton, "Description of a New Fish from the Lower Chalk of Dover," 'Quart. Journ. Geol. Soc.,' Vol. xxxiv (1878), pp. 439-446, Pl. xix.

§ F. Dixon, 'Foss. Suss.,' p. 376-7, Pl. xxx, Fig. 31, Pl. xxxv, Fig. 1.

Genus *Pachyrhizodus*, Dixon.

The teeth of this genus have so much resemblance to those of a reptile of the type of *Mosasaurus*, that they are often mistaken for such. One fossil, indeed, as already remarked (p. 280), forms the type of Owen's "*Mosasaurus*" *gracilis;* another fragment of the mandible, as already recognized by Mr. William Davies, in labelling the collection of the British Museum, has been described as the upper jaw of an unknown saurian, *Acrodontosaurus Gardneri;*[*] and the possibly reptilian character of other specimens was discussed by Mr. Toulmin Smith, so long ago as 1846.[†]

The teeth are round and conical, with more or less recurved tips, and possess a long, stout base, hollow, and anchylosed to the jaw, but partly enclosed in a socket, incomplete on all sides except the outer. The premaxilla [‡] is horizontally broadened, though not deep, and bears a single series of moderate-sized teeth upon its outer border, with two relatively large "tusks" within. The maxilla and dentary bone of the mandible are each armed with a single series of the teeth. The last-named bone is very deep, thick, and sometimes much curved transversely; it very rapidly tapers in front, bending inwards to meet its fellow of the opposite side in a small swollen symphysis. The skull is wide and depressed, and the bones are destitute of external ornamentation. The vertebræ are deeper than long, showing short, delicate, longitudinal rugæ on the sides. The scales (Pl. I, Fig. 8) are much overlapping, having the exposed portion marked with a few discontinuous radiating grooves (as shown by Brit. Mus., No. P. 1808).

---

[*] J. Wood Mason, "On a new Acrodont Saurian from the Lower Chalk," 'Quart. Journ. Geol. Soc.,' Vol. xxv, 1869, pp. 442-4, Pl. xix.

[†] Toulmin Smith, "On the Discovery of the Remains of a very remarkable Reptile or Fish in the Chalk of Kent," Charlesworth's 'London Geol. Journ.,' 1846, pp. 21-2. This group of fossils is now in the British Museum, and belongs to *Pachyrhizodus Gardneri.*

[‡] This is the bone shown in Dixon's 'Foss. Suss.,' Pl. xxxiv, Fig. 9.

The most important contribution to our knowledge of *Pachyrhizodus* is that by Prof. Cope,* published in 1875 ; but much remains to be learned in regard to the characters of the fins and the affinities of the fish. The small English fossils made known by Dixon (*op. cit.*) are named *P. basalis*, and if the larger specimens, like those included by Agassiz in "*Hypsodon lewesiensis*,"† are specifically distinct both from this and from the American forms, they must receive the name of *P. Gardneri*—the portion of mandible made known by Wood Mason as *Acrodontosaurus Gardneri* being the first fragment of the species recognizably described and figured, with a name. Owen's "*Mosasaurus gracilis*" probably represents a third species, to be known henceforth as *Pachyrhizodus gracilis.*

Genus *Stratodus*, Cope.

This genus was founded by Prof. Cope‡ upon the maxillæ, premaxillæ, and palatine bones of a fish from the Cretaceous Blue Limestone of Fort Wallace, U.S.A., remarkable on account of its singular dentition. The teeth are anchylosed to the jaw and placed in two or more series ; they are hollow, more or less cylindrical in section, and have the base of great length, with a relatively small, sharp-edged pointed crown. In the fossils each tooth is thus almost white in colour for the greater part of its length, merely capped with a black tip. No similar specimens have hitherto been recorded from the English Chalk, but I have met with a few examples in the National Collection, which appear to differ only from Cope's *S. apicalis* in having the teeth less curved, with somewhat larger crowns. They may thus be known as *Stratodus anglicus.* One bone from Glynde, Sussex (No. 49,906), of which a portion of the dentition is shown in Pl. I, Fig. 3, is very similar in character and dimensions to the so-called palatine of the American species, though it has much the appearance of an external element. It is associated with indeterminable crushed bones, of which one large piece shows a slight ornament of irregular parallel rugæ. Another detached portion of bone (No. 49,780), shown in

---

* E. D. Cope, 'Vert. Cret. Form. West,' pp. 220-226, with plates.

† L. Agassiz, 'Poiss. Foss.,' Vol. v, p. 99, Pl. xxva, Figs. 1, 2, 4; Pl. xxvi, Figs. 4, 5.

‡ E. D. Cope, 'Vert. Cret. Form. West,' 1875, pp. 226-7, Pl. xlix, Figs. 6-8.

Pl. I, Fig. 4, is shaped like the anterior part of the dentary of *Pachyrhizodus*, but agrees in size and characters with *Stratodus*, and shows the points of insertion of two rows of teeth, which have unfortunately been broken away; the external surface has a wrinkled appearance. The originally exposed surfaces of these and other similar fossils exhibit a curious greenish-grey dull appearance, by which they are readily recognizable.

Genus *Enchodus*, Agassiz.

Some fragmentary remains of a predaceous fish, with powerful dentition, not uncommon in the Chalk, were described by Agassiz under the generic name of *Enchodus*.* Prof. Cope † subsequently investigated the genus, but still only with imperfect materials; and more or less complete fishes of the same type, perhaps generically distinct, have also been discovered in the Cretaceous of Westphalia and Mount Lebanon.

The skull of *Enchodus* (Pl. I, fig. 5) ‡ is of triangular form, with flattened roof, but not much depressed, and only the postero-lateral portions of the cranial roof are sculptured. The margin of the upper jaw is formed by a deep thin premaxilla (*pmx*) and a long slender maxilla (*mx*), the latter being placed partly behind the former; and upon this margin are arranged small teeth. The premaxilla is the bone shown in the lower right-hand corner of Fig. 1 upon Agassiz's Plate xxv*c*, *tom. cit.*, and its teeth are larger than those of the maxilla, and differ in being few and widely spaced.§ The palatine (Pl. I, fig. 6, *pal.*) and ectopterygoid (*id.*, *ectp.*) are strong bones, and bear a powerful dentition, not placed in sockets, but firmly anchylosed. The palatine is an especially robust element, and is provided with a single long terminal tooth; it is one of the most commonly discovered parts of the fish, and has been erroneously described hitherto as the premaxilla.‖ The lower jaw (Pl. I, fig. 5, *d*) is moderately deep, and, like the opercular bones, is externally ornamented with series of minute tuberculations ; it bears a row of large teeth, spaced at long irregular distances, and external to these is a closely-set series of small teeth. All the teeth of both jaws exhibit considerable lateral compression for the greater part of their length, and thus have one or two opposing sharp edges. The sides of the vertebræ are impressed with deep longitudinally-extended pits.

---

* L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. i, p. 64.

† E. D. Cope, 'Vert. Cret. Form. West,' pp. 238-240.

‡ The following notes are based upon a skull of *Enchodus Faujasii* from Maastricht (Brit. Mus., No. 42,976), and two of *E. levesiensis* from Sussex (Brit. Mus., No. P. 5415, and Willett Coll., No. 65).

§ The supposed premaxilla of *Enchodus* described by H. E. Sauvage, 'Bull. Soc. géol. France' [3], Vol. xi (1883), appears to the present writer to be the anterior extremity of the dentary bone.

‖ Except by H. B. Geinitz ("Das Elbthalgebirge in Sachsen," in 'Palæontogr.,' Vol. xx, Pt. ii, Pl. xli, Figs. 13, 14), who describes one specimen as the anterior extremity of the mandible.

The single recognized species from the English Chalk was originally described as *Esox lewesiensis* by Mantell,[*] and must thus be known as *Enchodus levesiensis.* It was, however, re-named by Agassiz *Enchodus halocyon*,[†] and the same naturalist described a second larger species, *E. Faujasii*, from the Upper Cretaceous of Maastricht, Holland. The latter has not yet been discovered elsewhere, unless some of the larger English fossils are correctly referable to it.

Genus *Cimolichthys*, Leidy.

In his great work Agassiz[‡] described and figured a fragment of bone bearing semi-barbed teeth from the Chalk of Lewes, which he considered to belong to a species of *Saurocephalus*, made known by Hays in the United States under the name of *Saurodon Leanus*.[§] Dr. Leidy,[‖] however, subsequently pointed out that the English and American fossils were generically distinct, proposing the new name of *Cimolichthys levesiensis* for the former ; and more recently Mr. E. T. Newton[¶] has carefully studied the subject, extending Leidy's results, and showing that the semi-barbed teeth are fixed upon the palatine and pterygoid bones of an otherwise unknown fish. Similar teeth have also been described on the Continent as the dorsal fin-spines of a shark (*Spinax marginatus*, Reuss), and as possibly referable to the Teleostean *Anenchelum* (= *Lepidopus*).[**]

---

[*] G. A. Mantell, 'Foss. South Downs,' p. 237, Pl. xxxiii, Figs. 2-4; Pl. xli, Figs. 1, 2.

[†] L. Agassiz, 'Poiss. Foss.,' Vol. v. Pt. i, p. 64, Pl. xxvc, Figs. 1-16.

[‡] L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. i, p. 102, Pl. xxvc, Figs. 30, 31.

[§] J. Hays, "Description of a Fragment of the Head of a new Fossil Animal" (*Saurodon*), 'Trans. Amer. Phil. Soc.,' N.S., Vol. iii (1830), pp. 471-477, Pl. xvi.

[‖] J. Leidy, "Remarks on *Saurocephalus* and its Allies," 'Trans. Amer. Phil. Soc.,' Vol. xi (1857), p. 95.

[¶] E. T. Newton, "Remarks on *Saurocephalus*, and on the Species which have been referred to that Genus," 'Quart. Journ. Geol. Soc.,' Vol. xxxiv (1878), pp. 789-792.

[**] References to these various determinations will be found in a recent paper by W. Dames, "Die Gattung *Saurodon*, Hays," 'Sitzungsb. Ges.

The undescribed specimens in the British Museum add considerably to our knowledge of the fish—especially a fine skull and mandible from the Chalk of Lewes (No. P. 5491). The skull is depressed, and the hinder lateral portions of the roof are ornamented with fine radiating, tuberculated ridges, resembling those of *Enchodus* and *Pomognathus*. The premaxillæ and maxillæ are long and slender, with very small teeth; but the palatines and ectopterygoids are strong and bear a series of powerful teeth, anchylosed directly to the bone, many being of the familiar semi-barbed shape. The dentary bone of the mandible* is thin, but so bent that it has a wide horizontal extent; there is a single row of large recurved teeth, slightly compressed, with sharp edges near the apex, and not barbed, placed at long and irregular intervals; outside there is a close series of much smaller but similar teeth; and on the extreme outer margin there is a very minute row. The remainder of the skeleton is still unknown.

The above description shows that the so-called "*Saurocephalus striatus*," Agass., cannot belong to this genus—a possibility suggested, with hesitation, both by Dr. Leidy (*loc. cit.*, p. 94) and by Mr. E. T. Newton (*loc. cit.*, p. 793).

Genus *Pomognathus*, Dixon.

The skull of *Pomognathus* is scarcely distinguishable, upon a superficial glance, from that of *Cimolichthys*, but there are some differences in the dentition. The palatine and ectopterygoid are armed with large sharply-pointed, laterally-compressed teeth, anchylosed to the bone, and not barbed; and these teeth are largest in the middle of the arcade thus formed, diminishing towards either extremity. The premaxilla and maxilla are long and slender, the latter half-overlapping the former. The premaxilla is provided with two or more rows of very minute teeth, and the hinder portion of the maxilla bears a series of large, widely-spaced, anteriorly-directed teeth, immediately above which is seen an ornamented jugal bone. The mandible is also shaped like that of *Cimolichthys*, but is externally ornamented with tuberculated ridges; there are numerous large recurved conical teeth, of irregular sizes, placed in several rows within, and similar

---

Naturf. Fr. Berlin,' 1887, pp. 72-78. Prof. Dames has unfortunately overlooked the papers by Leidy and Newton quoted above, and has apparently not referred to Hays' original description; he thus erroneously supposes that the European detached teeth are identical with those of the American fossil.

* Figured by Dixon, 'Foss. Suss,' Pl. xxxii*, Fig. 10.

very minute teeth are clustered upon the margin. Dixon * figures the nearly complete fish, named *P. eupterygius*, in Mr. Willett's collection, but the details of structure are unfortunately not indicated.

As already detected by Mr. William Davies, while labelling the fossils in the British Museum, one of the skulls from Lewes assigned by Agassiz † to *Osmeroides levesiensis*, truly belongs to *Pomognathus eupterygius*, and the upper dentition there shown is that of the ectopterygoid and palatine.

Genus *Dercetis*, Agassiz.

The fishes of this genus are much elongated, and readily recognized by the longitudinal series of arrowhead-shaped scutes arranged upon the entire length of the trunk. The jaws are armed with powerful recurved teeth, though it is not definitely determined upon which bones these are fixed. The vertebræ are long and constricted in the middle, and the base of the neural arch is always very broad. The fins of the single recognized English species, *D. elongatus*,‡ are unknown.

One series of the dermal scutes is perforated by the canal of the "lateral line," and these dermal defences are often beautifully ornamented with minute spinelets, in addition to the usual median thorn-shaped prominence. Dr. G. J. Hinde has kindly submitted to me a perfect specimen obtained from a cavity in a flint nodule, which forms a most beautiful object for microscopical examination. It is shown from above, eight times the natural size, in Pl. I, fig. 7.

Remarkable elongated fossils consisting of a conglomeration of scales and fin-rays have also been referred to *Dercetis*. Some were originally described by Mantell § under the name of *Muræna? lewesiensis;* and two fragments were afterwards included by Agassiz ‖ among the type-specimens of *Dercetis elongatus*. As already pointed out by Mr. William Davies, ¶ however, these fossils rarely show the *Dercetis* scutes, but exhibit the scales of several genera of fishes confusedly mingled together, and they may thus be almost certainly regarded as the linings of worm-burrows. Similar fossils have been described by Dr. Anton Fritsch, from the Chalk of Bohemia, under the name of *Lepidenteron longissimum.*[*]

---

* F. Dixon, 'Foss. Suss,' p. 367, Pl. xxxv, Figs. 6, 7.

† L. Agassiz, 'Poiss. Foss.,' Vol. v, Pl. lx*b*, Figs. 3, 4.

‡ L. Agassiz, 'Poiss. Foss.,' Vol. ii, Pt. ii, p. 258, Pl. lxvi*a*, Figs. 1, 2, 5-8 (*non* Figs. 3, 4).

§ G. A. Mantell, 'Foss. South Downs,' 1822, p. 232, Pl. xxxiv, Fig. 10; Pl. xl, Fig. 2.

‖ L. Agassiz, 'Poiss. Foss,' Vol. ii, Pt. ii, Pl. lxvi*a*, Figs. 3, 4.

¶ W. Davies, "On some Fish Exuviæ from the Chalk, generally referred to *Dercetis elongatus*, Ag.," 'Geol. Mag.' [2], Vol. vi (1879), pp. 145-148.

It may further be pointed out that Agassiz's description of the fins of *Dercetis* is in no respects confirmed by any of the English fossils I have had the opportunity of examining, and was probably founded upon the Westphalian specimen briefly noticed as "*Dercetis scutatus*, Münst. et Agass." If so, it seems almost certain that the latter is identical with the specimens of a distinct genus subsequently described by W. von der Marck[†] under the name of *Pelargorhynchus*. Upon present evidence the fossils from the English Chalk are indistinguishable from those named *Leptotrachelus*, W. von der Marck, from Westphalia and Mount Lebanon.[‡]

Genus *Plinthophorus*, Günther.

This genus is founded upon a nearly complete fish, wanting the head, from the Lower Chalk of Folkestone, and is evidently allied to *Dercetis*.[§] The body is oblong, without scales, but is described as possessing a dorsal and ventral series of imbricate, arrow-head-shaped, long scutes on each side. Each scute has a low longitudinal median keel upon the external surface, and the broad, hinder, exposed portion is marked by a rugose ornament, and slight radiating ridges. The paired fins are well-developed, without spinous rays ; and the pelvics, which are abdominal in situation, consist each of about ten rays. The dorsal fin is of small extent, opposite the pelvics; the anal is short, mid-way between the pelvics and the caudal, and the latter fin is forked. The vertebral column consists of about sixty well-ossified vertebræ, each constricted in the middle and marked by small longitudinal furrows. The single known species is *P. robustus*.

---

[*] A. Fritsch, 'Rept. u. Fische böhm. Kreideform,' p. 19.

[†] W. von der Marck, 'Ueber einige Wirbelthiere, &c., der Westfälischen Kreide," 'Zeitschr. deutsch. geol. Ges.,' Vol. x (1858), p. 242; and "Fossile Fische, &c., aus dem Plattenkalk der jüngsten Kreide in Westphalen," 'Palæontographica,' Vol. xi (1863), p. 61, Pl. xi, Pl. xii, Fig. 3.

[‡] See especially figures by J. W. Davis, "Foss. Fishes Mt. Lebanon," 'Trans. Roy. Dubl. Soc.' [2], Vol. iii (1887), Pl. xxxviii, Figs. 1-3.

[§] A. Günther, "Description of a New Fossil Fish from the Lower Chalk," 'Geol. Mag.,' Vol. i (1864), pp. 114-118, Pl. vi.

Genus *Protosphyræna*, Leidy.

The detached teeth of this genus are among the commonest of Chalk fossils, and the history of the acquisition of our present knowledge of the fish to which they belong is lengthy and intricate. Messrs E. T. Newton[*] and William Davies[†] have both published critical summaries of the literature of the subject, and it will, therefore, be sufficient here merely to give a succinct account of the main points.

The teeth are laterally-compressed and lanciform, without marginal serrations, and when found in connection with the jaw are seen to be fixed in distinct sockets. They were first noticed in 1822 by Dr. Mantell,[‡] who described one example as belonging to an unknown fish, and referred a second to an undetermined species of shark. Twenty-one years later Prof. Agassiz studied the fossils, and thought that they were most probably identical with certain teeth discovered by Dr. Harlan[§] in the Cretaceous strata of North America, which had been described under the name of *Saurocephalus lanciformis*, and erroneously placed among the Reptilia. They were accordingly made known as such in the great work on the 'Poissons Fossiles';[||] and the determination was subsequently adopted by Dixon,[¶] in 1850, who figured more satisfactory specimens. At this time, moreover, an important addition to our knowledge of the species was rendered possible by a fine fossil in Sir Philip Egerton's collection, which showed that the fish had a remarkably elongate snout. Six years afterwards Prof. Leidy[**] carefully re-examined Dr. Harlan's original American specimens of *Saurocephalus*, and soon became convinced that Agassiz was mistaken in supposing that the English fossils were identical with these even generically. He thus proposed a new generic and specific name—*Protosphyræna ferox*—for the specimens figured by Mantell, Agassiz, and Dixon; wrongly suggesting, however, that Sir Philip Egerton's fossil rostral bone truly belonged to a sword-fish, which might be appropriately termed *Xiphias Dixoni*. Between 1875 and 1877, remains similar to those of the English Chalk were actually discovered in America, and not only proved that Egerton and Dixon were right in deciding upon the reference of the long snout to *Protosphyræna*, but also added further important anatomical details. Prof. Cope, however, who described these fossils,[*] proposed the difficultly pronounceable name of *Erisichthe*, which happily becomes a synonym.

---

[*] E. T. Newton, "On *Saurocephalus*," 'Quart. Journ. Geol. Soc.,' Vol. xxxiv (1878), pp. 786-796.

[†] W. Davies, "On the Nomenclature of *Saurocephalus lanciformis* of the British Cretaceous Deposits; with Description of a New Species (*S. Woodwardii*)," 'Geol. Mag.' [2], Vol. v (1878), pp. 254-261, Pl. viii.

[‡] G. A. Mantell, 'Foss. South Downs,' p. 227, Pl. xxxiii, Figs. 7-9.

[§] R. Harlan, "On a New Fossil Genus of the Order Enaliosauri, Conyb.," 'Journ. Acad. Nat. Sci. Philad.,' Vol. iii (1824), pp. 331-337, Pl. xii, Figs. 1-5.

[||] L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. i, p. 102, Pl. xxv*c*, Figs. 21-29.

[¶] F. Dixon, 'Foss. Suss.,' p. 374, Pl. xxx, Fig. 21; Pl. xxxi, Fig. 12; Pl. xxxii,* Fig. 1; Pl. xxxiv, Fig. 11.

[**] J. Leidy, "Remarks on *Saurocephalus* and its Allies," 'Trans. Amer. Phil. Soc.,' Vol. xi (1860), pp. 91-95.

Only one species of *Protosphyræna* (*P. ferox*, Leidy) has hitherto been detected in the English Chalk, and but little is known as to the systematic position of the genus. The name was originally suggested by the form of the teeth, which are not very unlike those of the living *Sphyræna*; but it is now certain that the fossil form cannot be placed in immediate proximity to the latter. The structure of the lower jaw is described as being very complex.

With *Protosphyræna* I would also venture to associate the fragment of snout described by Agassiz[†] as *Tetrapterus minor*. The caudal vertebræ made known at the same time may also be provisionally placed here, for they are quite distinct from those of the living *Tetrapterus* (=*Histiophorus*).

The fins of *Protosphyræna* were originally described by Agassiz[‡] as the dorsal fin-spines of the Selachian fish *Ptychodus*, and were first recognized as Teleostean by Prof. Cope,[§] who referred them to a genus *Pelecopterus*, indicating a previously unknown order (*Actinochiri*) and family (*Pelecopteridæ*). Each of these fossils is "composed of parallel rods in close apposition. The anterior edge being oblique, the extremities of the rods terminate successively at the border, which is trenchant, constituting the offensive part of the spine. The edge is hardened and the adjacent parts of the spine thickened, and in some cases roughened by a deposit of a hard substance resembling enamel. It is either straight, or regularly undulate or serrate, with recurved, acute, tooth-like processes. The smaller species exhibit the serrate character; the larger, the regular border" (Cope).*

---

[*] E. D. Cope, 'Vert. Cret. Form. West,' 1875, pp, 217-218. Also E. D. Cope, "On the Genus *Erisichthe*," 'Bull. Geol. Surv. Territ.,' Vol. iii (1877), pp. 821-823.

[†] L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. i, p. 91, Pl. lx*a*, Figs. 9, 10.

[‡] L. Agassiz, 'Poiss. Foss.,' Vol. iii, pp. 56-59, Pl. x*a*, x*b*, Fig. 18.

[§] E. D. Cope, 'Vertebrata Cret. Form. West,' 1875, pp. 244*a-f*.

Genus *Osmeroides*, Agassiz.

Much still remains to be discovered in regard to the characters and relationships of the various fossils referred by Agassiz to *Osmeroides*.† The genus was founded upon some fishes from the Westphalian Chalk, which appeared to possess an adipose dorsal fin, and were considered to be closely allied to the living Smelts (*Osmerus*), being distinguished mainly by their more depressed and rounded trunk, and the breadth of the pedicle of the tail. These specimens showed no traces of scales (though such have subsequently been discovered), and in associating with them an English Chalk fossil provided with robust scales, Agassiz expressed some doubts as to its generic identity. W. von der Marck afterwards‡ decided that the Westphalian fishes possessed no adipose dorsal fin, and were thus most probably *Clupeidæ;* and, in the case of these, he proposed to substitute the name of *Sardinioides* for *Osmeroides*, leaving the latter term to apply only to the English specimens. Whatever may be the result of future researches, it will de convenient here to retain the familiar name of *Osmeroides levesiensis* for the fish of the Lewes Chalk.

The latter was originally described by Mantell§ as *Salmo lewesiensis*, and has been well figured both by Agassiz‖ and in Mantell's own popular works. The skull is much depressed, with flattened roof, and the bones are ornamented with a marked rugosity. The teeth must have been minute and clustered upon the margin of the jaws. The dorsal fin is short, placed almost in the middle of the back, and the pelvic fins are small, and not quite opposite to the dorsal, being placed more posteriorly. All the fin-rays are very robust. The scales are cycloid and deeply overlapping, either without external ornament, or faintly rugose.

Under the name of *Osmeroides crassus*, Dixon¶ briefly notices a fine head, with anterior portion of the trunk, from the Chalk of Southeram, in Mr. Willett's collection. So far as known, it seems to differ from *O. levesiensis* mainly in the characters of the dentition. The premaxilla is short and stout, with a single large conical tooth well within the mouth, and other smaller ones near the outer border. The maxilla is relatively long, with a series of small marginal teeth; and the dentition of the lower jaw is very powerful.

---

* This amended paragraph has been added since the reading of the paper, from information kindly furnished by Prof. E. D. Cope and Mr. William Davies.

† L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. ii, p. 103.

‡ W. von der Marck, "Fossile Fische, etc., aus dem Plattenkalk der jüngsten Kreide in Westphalen," 'Palæontographica,' Vol. xi (1863), pp. 41-45.

§ G. A. Mantell, 'Foss. South Downs,' 1822, p. 235, Pl. xl, Fig. 1; Pl. xxxiii, Fig. 12; Pl. xxxiv, Figs. 1, 2.

‖ L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. ii, pp. 105-107, Pl. lx*b*, Figs. 1, 2, 5-7, Pl lx*c*. (*Non*. Pl. lx*b*, Figs. 3, 4; see above, p. 318.)

¶ F. Dixon, 'Foss. Suss.,' p. 376.

Some fishes from the Cretaceous of Mount Lebanon have also been described under the name of *Osmeroides* by Messrs. Pictet and Humbert* and J. W. Davis.†

Genus *Acrognathus*, Agassiz.

This is a small, very rare fish, with elongate, rounded body, and broad, depressed head, placed by Agassiz‡ among the *Salmonidæ*, and believed by Dr. Günther § to be a deep-sea representative of that family. The orbits are enormous—a circumstance which suggested the name of *A. boops* for the only known species. The lower jaw is very deep, and the teeth exceedingly minute. The pelvic fins are abdominal, and the dorsal is placed immediately opposite to them. The anal fin is remote. The scales are large, smooth, without posterior crenulations, and deeply overlapping.

The type-specimen of *Acrognathus boops* was obtained by Dr. Mantell from the Upper Chalk of Lewes ; and there is a second fragment in the British Museum, showing the mandible and some vertebræ, from Shalford, near Guildford, determined by Mr. William Davies.

Genus *Aulolepis*, Agassiz.

Aulolepis also seems likely to have been a deep-sea Salmonoid, as suggested by Agassiz and Günther (*op. cit.*). The body is rounded and the head correspondingly depressed. The teeth on the margin of the jaw are very small, and the maxilla is large, being dentigerous, and entering considerably into the formation of the upper jaw. The pelvic fins are apparently abdominal, though slightly advanced forwards; and one or two of the long anterior rays of the dorsal fin seem to be spinous. All the fins are powerful

---

* F. J. Pictet et A. Humbert, 'Nouvelles Recherches sur les Poissons fossiles du Mont Liban,' 1866, p. 77.

† J. W. Davis, "Foss. Fishes Mt. Lebanon," 'Trans. Roy. Dublin Soc.' [2], Vol. iii, 1887, pp. 557-567, Pls. xxxi, xxxii.

‡ Agassiz, *op. cit.*, Vol. v, Pt. ii, p. 108, Pl. lx*a*, Figs. 1-4.

§ A. Günther, 'Study of Fishes,' 1880, p. 631.

—the caudal especially so. The scales are very large, smooth, without posterior serrations, and deeply overlapping; those of the "lateral line" are more truncate posteriorly than the remainder, and each of the series bears a little "pipe" for the reception of the slime-canal with its sense-organs—a feature giving rise to the name of the genus ("pipe-scale").

The single recognized species is *Aulolepis typus*,* founded upon one of Dr. Mantell's fossils from Lewes. Two much more satisfactory specimens are now preserved in the British Museum, from the Lower Chalk of Burham, Kent, and the higher beds of Dorking, Surrey.

Elopine Clupeoid Fishes.

No remains of undoubted Clupeoids have hitherto been recorded from the English Chalk; but I have seen several specimens of undescribed allies of the primitive existing *Elops*, and one very large genus and species is indicated by fossils in the British and Woodwardian Museums. One Elopine Clupeoid from the Lowermost Chalk of Bohemia bears the name of *Elopopsis Heckeli*.†

Physoclystous Teleosteans.

In this group of Teleostean fishes the air-bladder, when present, is not connected by a duct with the alimentary canal in the adult. Except in the Flat-fishes and Cod-fishes (*Anacanthini*), some of the rays of the dorsal, anal, and pelvic fins are always converted into spines. The tooth-bearing margin of the upper jaw is most commonly formed entirely by the pre-maxilla to the exclusion of the maxilla; and the pelvic fins are, in the majority, placed very far forwards.

Genus *Calamopleurus* (Agassiz), Dixon.

Among the undefined genera mentioned by name only in the 'Poissons Fossiles' is that of *Calamopleurus*,‡ proposed to be founded upon a Cretaceous fish from the North of Brazil. It was first established by Dixon,§ in an unsatisfactory manner, upon a similar fossil in Sir Philip Egerton's collection, from the Chalk of Kent, which was figured and briefly noticed under the name of *Calamopleurus anglicus*. As shown by the type specimen and by two others in the British Museum (Nos. 36,170 and 49,055), the trunk of the fish is cylindrical, exhibiting little lateral compression; and the skull is small, with flattened roof, unornamented, and only marked by the pits of the sensory canals. The sclerotic capsule seems to have been ossified. The maxilla is long and slender, with the tooth-bearing margin slightly arched and provided with a close series of very minute teeth; the mandible is relatively deep, and bears a single row of elongate conical teeth, slightly curved, and considerably larger than those of the upper jaw, though likewise closely set. The opercular bones are large—especially the pre-operculum, which has a broad, thickened, anterior margin, from which radiating ridges and furrows diverge backwards. The scales are enormous, cycloid, and deeply overlapping, and show no markings beyond the concentric lines of growth, and some very faint divergent ribs revealed upon the exposed portion by the magnifying lens. There are two dorsal fins with spinous rays, and the pelvic fins are abdominal. Agassiz is probably correct in placing the genus with the Grey Mullets in the family of *Mugilidæ*.

---

* L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. ii, p. 109, Pl. lxa, Figs. 5-8.

† A. E. Reuss, "Neue Fischreste aus dem böhmischen Pläner," 'Denkschr. math-naturw. Cl. k. Akad. Wiss.,' Vol. xiii (1857), pp. 39-41, Pl. iii.

‡ L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. i, p. 122.

§ F. Dixon, 'Foss. Suss.,' p. 375, Pl. xxxii, Fig. 12.

Prof. Cope* has described a genus, *Syllæmus*, from the Cretaceous of North America, which is very closely allied to *Calamopleurus*, and may even be identical. According to the description, however, *S. latifrons* seems to have a narrow mandible destitute of teeth, though this may perhaps be merely owing to imperfect preservation.

Genus *Cladocyclus*, Agassiz.

Two large oval scales, from the Chalk of Lewes, were originally figured by Agassiz† as pertaining to *Hypsodon*, but subsequently removed from that " genus " by the same naturalist (*ibid.*, p. 103) after he had had the opportunity of studying a more complete fossil from the Cretaceous rocks of North Brazil. The latter exhibited similar scales in natural association with vertebræ, which appeared very different from those most probably referable to *Hypsodon*; and Agassiz therefore regarded the fossils as indicating a new genus, for which the name of *Cladocyclus* suggested itself as most appropriate, in reference to the supposed branched condition of the canals forming the "lateral line" of the fish. Each of these scales is oval in shape, the long axis being vertical; and they were evidently deeply overlapping. The exposed portion is a sector only forming about one-third of the whole scale, and this is ornamented by numerous rounded tubercles, each with a pit in the middle. The overlapped area is marked by the delicate concentric lines of growth, and large interrupted diverging furrows; and I have seen no evidence of the branched condition of the "lateral line" referred to by Agassiz. A single English species has hitherto been recognized, namely, *C. levesiensis;* and the scales of the Brazilian form, *C. Gardneri,*[*] are very similar, but have slight concentric undulations parallel with the exposed posterior margin.

---

* E. D. Cope, " Report upon the Extinct Vertebrata obtained in New Mexico," ' Rep. U.S. Geol. Surv. Territ.,' Part ii, Vol. iv. (Palæontology), 1877, pp. 26-28, Pl. xxiii, Fig. 1. (*Syllæmus* was first founded in 1875, ' Vert. Cret. Form. West.,' p. 180.)

† L. Agassiz, ' Poiss. Foss.,' Vol. v, Pl. xxv*a*, Figs. 5, 6.

Genus *Platax*, Cuvier.

A small fossil from the Chalk of Washington, Sussex, was figured and briefly noticed by Dixon[†] under the name of *Microdon nuchalis.* This, however, is now preserved in the British Museum, and I have discovered that it is truly a Teleostean fish.[‡] It is unfortunately too imperfect to be capable of very precise determination, but it is evidently an ally of the living "Sea-bats," and may be placed until more satisfactory specimens are available in the genus *Platax*, under the name of *P. nuchalis.* The body is deep, with the remains of large dorsal interspinous bones, indicating the original presence of a very high dorsal fin. The vertebral column is well ossified; and there is a distinct spine in front of each pelvic fin. Very similar, but perfect, fossils have been ascribed to *Platax* from the Upper Cretaceous of Mount Lebanon.[§]

Genus *Beryx*, Cuvier.

To the type-genus of the *Berycidæ*, *Beryx* itself, only a single English Chalk species can be referred with much certainty—the *B. radians*, Agassiz.[||] The living forms possess a relatively short dorsal fin, with three or four slender spines; and the spinous portion of the anal is similarly insignificant.* The Cretaceous *Beryx radians* appears to agree in these respects with the surviving species, but it is especially characterized by the enormous size of the pelvic fins (Pl. I, fig. 9), which reach backwards as far as the anal. The scales are of moderate size, smooth, and very delicately serrated on the posterior margin. A second Chalk species, *B. microcephalus*, Agass.,† is more doubtfully placed in this genus, and is readily distinguished by the extremely strong serrations of the posterior border of the scales. It is a small form, with relatively small head, and powerful dentition; but the fins, though robust, are imperfectly known.

---

[*] Named only by Agassiz, 'Poiss. Foss.,' Vol. v, Pt. i, p. 103.

[†] F. Dixon, 'Foss. Suss.,' p. 369, Pl. xxxii, Fig. 7.

[‡] Smith Woodward, "On the so-called *Microdon nuchalis*, Dixon, from the Chalk of Sussex, a new Species of *Platax*," 'Ann. and Mag. Nat. Hist.' [5], Vol. xx (1887), pp. 342-4.

[§] F. J. Pictet, 'Poissons Fossiles du Mont Liban,' 1850, p. 19, Pl. ii, Fig. 1. Pictet and Humbert, 'Nouv. Rech. Poiss. Foss. Mt. Liban,' 1886, p. 48, Pl. iv, Figs. 1-3. J. W. Davis, "Foss. Fishes Mt. Lebanon," 'Trans. Roy. Dublin Soc.' [2], Vol. iii, 1887, p. 524, Pl. xxv, Fig. 4.

[||] Agassiz, 'Poiss. Foss.,' Vol. iv, p. 118, Pl. xiv*b*, Fig. 7; Pl. xiv*c*, Figs. 7-9. Dixon, 'Foss. Suss.,' p. 371, Pl. xxxvi, Fig. 4.

Remains of the true *Beryx* also appear to have been discovered in the Chalk of Mt. Lebanon (*B. vexillifer* and *B. ovalis*).‡

Genus *Hoplopteryx*, Agassiz.

The genus *Hoplopteryx* was founded by Agassiz § upon a fish (*H. antiquus*) from the Chalk of Westphalia, much like *Beryx* in general form, but especially differing in the characters of the dorsal and anal fins. The dorsal fin occupies the greater part of the back, and the anterior spinous portion, consisting of six very strong spines, has as great an extent as the soft portion behind. There are also four large and strong spines in advance of the anal fin ; and the pelvic fins possess at least seven soft rays, in addition to the usual spine.

No English fossils were referred at the time to the same type, but it now appears that at least two species are represented in the Chalk of Kent and Sussex. The common so-called *Beryx levesiensis*, or *Beryx ornatus*,‖ is truly referable to *Hoplopteryx*, as shown by its dorsal and anal fins ; and so also (as Mr. J. W. Davis has pointed out*) is the large species called *Beryx superbus* by Dixon.† In *Hoplopteryx levesiensis* there are six powerful spines in advance of the dorsal fin, occupying as great a length of the back as the succeeding soft rays; and three (or possibly more) similar spines occur in front of the anal. Each pelvic fin has at least eight soft rays in addition to the spine ; and the posterior margins of the scales are strongly serrated. *Hoplopteryx superbus*, if really specifically distinct, and not merely differing in age, may be said to be distinguished by its stronger skeleton, fins, and scales ; and the latter seem to have a greater antero-posterior measurement in proportion to their height.

---

* A fine figure of the skeleton of a recent species has lately been published by A. Günther, "Report on the Deep-Sea Fishes," 'Challenger Reports,' Zoology, Vol. xxii (1887), Pl. vi.

† L. Agassiz, 'Poiss. Foss.,' Vol. iv, p. 119, Pl. xiv*b*, Figs, 3-6 ; Pl. xiv*c*, Fig. 10. Dixon, 'Foss. Suss.,' p. 372, Pl. xxxiv, Fig. 3.

‡ Pictet and Humbert, 'Nouv. Rech. Poiss. Foss. Mt. Liban,' p. 30, Pl. ii, Figs. 1-3. J. W. Davis, "Foss. Fishes Mt. Lebanon," 'Trans. Roy. Dublin Soc.' [2], Vol. iii, p. 508, Pl. xxvii, Fig. 4.

§ L. Agassiz, 'Poiss. Foss.,' Vol. iv, pp. 131, 2, Pl. xvii, Figs. 6-8.

‖ *Zeus lewesiensis*, Mantell, 'Foss. South Downs,' 1822, p. 234, Pls. xxxv, xxxvi. *Beryx ornatus*, Agassiz, 'Poiss. Foss.,' Vol. iv, p. 115, Pl. xiv*a*, Pl. xiv*b*, Figs. 1-2 ; Pl. xiv*c*, Figs. 1-6, Pl. xiv*d*. Also Dixon, 'Foss. Suss.,' p. 371, Pl. xxxvi, Fig. 3 ; Pl. xxxiv, Figs. 1, 4, 5. The species is also included in the genus *Beryx* in the present writer's "List of Fossil Berycidæ," 'Geol. Mag.' [3], Vol. iv (1887), pp. 357-8, which appears to include all fossil forms discovered before the date of publication, except *Beryx Valenciennesi*, Hébert, 'Mém. Soc. Géol. France' [2], Vol. v (1854), p. 349, Pl. xxvii, Fig. 2.

Genus *Berycopsis*, Dixon.

Berycopsis is a Berycoid with scales of moderate size, thick, and remarkable for the absence of serrations upon their posterior border. The scales are smooth, or only ornamented with very delicate radiating lines, visible under a lens. The fin-rays of the dorsal and anal fins are especially robust, and in advance of the former there are not less than six short, strong spines, gradually increasing in length posteriorly, and somewhat spaced out ; the soft portion of the fin seems to have been continuous with the spinous portion, but it is considerably higher. There are at least seven soft rays in each pelvic fin, in addition to the usual spine ; but the anal and caudal still remain unknown.

The only species hitherto recognized is *B. elegans*,‡ of which the type-specimen was obtained from the Chalk of Sussex, and is preserved in Mr. Willett's collection in the Brighton Museum.

Genus *Stenostoma*, Dixon.

This genus is founded upon a specimen in the Dixon Collection (British Museum), and probably belongs to the Berycidæ, though the characters of its fins are still imperfectly known. It is a little deep-bodied fish, with small, deeply overlapping ctenoid scales. The head-bones are coarsely marked with tubercles and ridges, and (as shown by No. 63, Willett Coll.) the operculum is of triangular shape. The single known species is *S. pulchella*,[*] and the fish may perhaps be related to the small-scaled existing *Trachichthys*;[†] but it certainly has no affinity with the Brazilian Cretaceous fossil, *Rhacolepis*, as suggested by Dixon, the latter having cycloid scales and pertaining to the herring-family.[‡]

---

* J. W. Davis, 'Foss. Fishes Mt. Lebanon,' p. 514. Mr. Davis also well remarks that the so-called *Beryx syriacus*, P. and H., belongs to this genus. The new species *Hoplopteryx spinosus*, Davis, however, is at least generically distinct, as shown by the characters of its median fins.

† F. Dixon, 'Foss. Suss.,' p. 372, Pl. xxxvi, Fig. 5.

‡ F. Dixon, 'Foss. Suss.,' 1850, p. 372, Pl. xxxv, Fig. 8.

Genus *Homonotus*, Dixon.

The genus *Homonotus* is too imperfectly known to be placed with certainty among the *Berycidæ*, though this is its most probable position. A single species, *H. dorsalis*, was figured by Dixon,[§] but no notice of it beyond the original brief paragraph appears to have been hitherto published.[‖] It differs from all other Berycoids of the Chalk in the thinness of its ctenoid scales; and also in the length and slenderness of the spinous rays in front of the dorsal fin. The last-named spines are not less than twelve in number, and the fin occupies the greater part of the back, commencing far in advance of the opposing anal, though it is uncertain whether the spinous and soft portions were connected. In front of the anal fin there are four large, strong spines successively increasing in size.

The precise nature of the following genera of fishes cannot be determined, owing to the imperfection of the fossils upon which they are respectively founded.

Genus *Cœlorhynchus*, Agassiz.

This uncertain genus was founded by Agassiz upon a slender elongated fossil which he considered to be the snout of an extinct Sword-fish.[¶] The fossil tapers at its extremity to a blunt point, but the base is unknown. It is round in section, with a small central cavity divided into two towards the upper end, and the external surface is longitudinally grooved. The extremity readily splits into two symmetrical halves along a division-plane in the wall dividing the internal cavity. According to Prof. Williamson,[*] the microscopical structure of the fossil is closely similar to that of the dermal armour of the Coffer-fish (*Ostracion*), and it is therefore almost certainly a dermal spine. Only one small species, *Cœlorhynchus cretaceus*,[†] is known from the Chalk; but much larger examples are discovered in the Eocenes. One fine specimen from the Bracklesham Beds in the British Museum (No. 25,729*a*) measures no less than ten inches in length, and its diameter at the base is only about half an inch.

---

[*] F. Dixon, 'Foss. Suss.,' p. 373, Pl. xxxvi, Fig. 2.

[†] See figures of A. Günther, 'Report on the Deep-Sea Fishes,' Pl. v, Figs. *c*, *d*.

[‡] Smith Woodward, "On the Fossil Teleostean Genus *Rhacolepis*," 'Proc. Zool. Soc.,' 1887, pp. 535-542, Pls. xlvi, xlvii.

[§] F. Dixon, 'Foss. Suss.,' p. 372, Pl. xxxv, Fig. 2.

[‖] A small fish described by Mr. J. W. Davis (*op. cit.*, p. 519, Pl. xxv, Fig. 3), from the Cretaceous of Mount Lebanon, under the name of *Homonotus pulcher*, is certainly not referable to this genus. The dorsal fin commences opposite the anterior extremity of the anal, and the thick scales are quite distinct in character. The specimen is, indeed, very suggestive of the genus *Pycnosterinx*.

[¶] L. Agassiz, 'Poiss. Foss.,' Vol. v, Pt. i, p. 92.

Genus *Ancistrodon* (Debey), Roemer.

The name of *Ancistrodon* was originally given by Debey, in MS., to some detached fish-teeth from the Chalk of Aix-la-Chapelle, and subsequently defined by Roemer,[‡] who discovered and described similar specimens in the corresponding formations of Texas, U.S.A. Bosquet and Ubaghs afterwards recorded other examples from the Chalk of Maastricht; in 1881 Schlüter figured and described the original teeth from Aix; and lastly, Prof. W. Dames,[§] of Berlin, has published an elaborate study of the "genus," defining several "species," both Cretaceous and Tertiary.

The teeth in question are readily recognized by their laterally-compressed form, and the peculiar shape of the crown, which is very suggestive of the claw of such an animal as a cat. This is hard and enamelled, and fixed upon a long base, which tapers and varies in width but slightly. I have met with several detached specimens from the English Chalk, and there are three in the British Museum. The smallest is from Hart Hill, near Charing, Kent; one, somewhat larger, from Lewes (Pl. I, Fig. 10); and another, of considerable size, from an uncertain locality in Sussex.

It is obviously unwise to propose specific names for fossils of so problematical a nature, and the "genus" itself must only be regarded as provisional. The teeth were originally referred in error to an extinct shark, and it cannot be said that their true relationships are still placed beyond doubt. They are regarded by Dames as the pharyngeal teeth of Teleosteans ; but it seems quite as likely that they are the anterior prehensile teeth of Pycnodonts.

---

[*] W. C. Williamson, "Investigations into the Structure and Development of the Scales and Bones of Fishes," 'Phil. Trans.,' 1849, Pl. xliii, Figs. 35-37; *ib.*, 1851, p. 668.

[†] F. Dixon, 'Foss. Suss.,' p. xii, Pl. xxxii, Fig. 10.

[‡] F. Roemer, 'Die Kreidebildungen von Texas und ihre organischen Einschlüsse,' 1852, p. 30, Pl. i, Fig. 10.

[§] W. Dames, "Ueber *Ancistrodon*, Debey," 'Zeitsch. deutsch. geol. Gesell,' 1883, pp. 655-670, Pl. xix. Full references to previous literature are given in this paper.

Genus *Plethodus*, Dixon.

Some portions of flat crushing teeth, from the Chalk of Sussex, were placed by Dixon* in a genus named *Plethodus*, and referred to fishes of the Selachian order ; and one similar specimen has subsequently been described by Fritsch as *Chimæra furcata*.† The thin superficial layer of these fossils is punctate, and the tooth-substance around each punctation has a concentric structure ; beneath this layer the tooth consists of vascular dentine, with the principal vessels at right-angles to the grinding surface ; and the base of the tooth is formed by a layer of true bone, with very distinct lacunæ. The plates are of varying form, sometimes oval, sometimes elongated and bifurcated at one extremity, sometimes convex, and sometimes concave ; those occurring in the Gault and Cambridge Greensand are also often leaf-shaped, with a depression at one end, and the vertical margin ornamented with small tubercles. Occasionally two plates are found naturally superposed, like the pharyngeal dental plates of the Eocene *Phyllodus*.

That these fossils are truly teeth appears certain ; but whether they are all of one character, and belong to one genus, may perhaps be considered doubtful. Many of them—if not all—belong undoubtedly to bony fishes. The teeth are occasionally found connected with bone, and one specimen in Mr. Willett's collection shows "*Plethodus*" so placed in the midst of a skull as to suggest its connection with the pharyngeal bones. Two species are recognized, *P. oblongus* and *P. expansus*.

IV.—REVISED LIST OF THE FOSSIL VERTEBRATA OF THE ENGLISH CHALK.

As a result of the investigations briefly summarized in the preceding pages, I venture to regard the following as a revised list of the English Chalk Vertebrata, so far as can be determined from known specimens. Of the species marked thus * the type-specimens are preserved in the British Museum, while of those marked

---

* F. Dixon, 'Foss. Suss.,' p. 366, Pl. xxxii*, Fig. 4; Pl. xxxiii, Fig. 2.

† A. Fritsch, 'Rept. u. Fische böhm. Kreideform.,' pp. 16, 17.

thus † the types are to be found in Mr. Willett's collection in the Brighton Museum.

REPTILIA.

Order CHELONIA.

* (?) *Chelone Hoffmanni.*
* *Cimoliochelys Benstedi* (Mantell), Owen.

Order SAUROPTERYGIA.

* *Polyptychodon interruptus*, Owen.
* *Plesiosaurus Bernardi*, Owen.
* „ *constrictus*, Owen.
* „ *Smithii*, Owen.

Order ICHTHYOSAURIA.

Ichthyosaurus campylodon, Carter.

Order PYTHONOMORPHA.

* *Mosasaurus anceps* (Owen), A. S. W.

Order LACERTILIA.

* *Dolichosaurus longicollis*, Owen.
† *Coniosaurus crassidens*, Owen.
Rhaphiosaurus subulidens, Owen.

Order PTEROSAURIA.

* *Ornithocheirus giganteus*, Bowerb.
* „ *Cuvieri*, Bowerb.
* „ *compressirostris*, Owen.

Order DINOSAURIA.

* *Acanthopholis horridus*, Huxley.

PISCES.

Order SELACHII.

* *Acrodus* (?) *Illingworthi*, Dixon.
* *Acrodus levis*, A. S. Woodw.
* *Corax falcatus*, Agass.
„ *pristodontus*, Agass.
* *Drepanephorus canaliculatus* Egert.
* *Synechodus dubrisiensis* (Mackie), A. S. W.
* *Notidanus microdon*, Agass.
„ *pectinatus*, Agass.

* *Odontaspis rhaphiodon*, Agass.
,, *subulata*, Agass.
* *Otodus appendiculatus*, Agass.
,, *crassus*, Agass.
,, *semiplicatus*, Münster.
* *Oxyrhina crassidens*, Dixon.
* ,, *Mantelli*, Agass.
* *Ptychodus decurrens*, Agass.
,, *latissimus*, Agass.
* ,, *mammillaris*, Agass.
* ,, *Oweni*, Dixon.
* ,, *polygyrus*, Agass.
,, *rugosus*, Dixon.
* *Scylliodus antiquus*, Agass.
† *Squatina Cranei*, A. S. Woodw.

Order CHIMÆROIDEI.

* *Edaphodon Agassizii* (Buckl.).
,, *crassus*, Newton.
,, *gigas*, Egert.
* ,, *Mantelli* (Buckl.).
,, *Sedgwickii*, Agass.
† *Elasmodectes Willetti*, Newton.
Ischyodus brevirostris, Agass. (*var.*).
,, *incisus*, Newton.

Order GANOIDEI.

† *Belonostomus attenuatus*, Dixon.
* ,, *cinctus*, Agass.
* *Cœlodus angustus* (Agass.), Zittel.
,, *cretaceus* (Agass.), Zittel.
* ,, (?) *faba* (Agass.), Zittel.
† ,, *parallelus* (Dixon), Zittel.
* *Gyrodus cretaceus*, Agass.
* *Lophiostomus Dixoni*, Egerton.
* *Macropoma Mantelli*, Agass.
† *Microdon* (?) *occipitalis*, Dixon.
* *Neorhombolepis excelsus*, A. S. Woodw.
* *Prionolepis angustus*, Egerton.
Rhombic-scaled ganoid, gen. non det.

Order TELEOSTEI.

* *Acrognathus boops*, Agass.
* *Aulolepis typus*, Agass.
† *Berycopsis elegans*, Dixon.
* *Beryx radians*, Agass.
* „ (?) *microcephalus*, Agass.
* *Calamopleurus anglicus*, Dixon.
* *Cimolichthys levesiensis*, Leidy.
* *Cladocyclus levesiensis*, Agass.
* *Daptinus* (?) *intermedius*, Newton.
* *Dercetis elongatus*, Agass.
* *Enchodus levesiensis* (Mantell), Agass.
† *Homonotus dorsalis*, Dixon.
* *Hoplopteryx levesiensis* (Mantell), A. S. W.
* „ *superbus* (Dixon), Davis.
* *Ichthyodectes elegans*, Newton.
* „ *minor* (Dixon), Newton.
* *Osmeroides levesiensis* (Mantell), Agass.
† „ (?) *crassus*, Dixon.
* *Pachyrhizodus basalis*, Dixon.
* „ *Gardneri* (Mason), Davies MS.
† „ *gracilis* (Owen), Davies MS.
* *Platax nuchalis* (Dixon), A. S. W.
† *Plethodus expansus*, Dixon.
† „ *oblongus*, Dixon.
* *Plinthophorus robustus*, Günther.
† *Pomognathus eupterygius*, Dixon.
* *Portheus Mantelli*, Newton.
* „ *Daviesii*, Newton.
* „ sp. ind., Newton.
* *Protosphyræna ferox*, Leidy.
* „ *minor* (Agassiz), A. S. W.
* *Saurocephalus* (?) *striatus*, Agass.
* *Stenostoma pulchella*, Dixon.
* *Stratodus anglicus*, A. S. Woodw.
Tomognathus mordax, Dixon.
Elopine Clupeoid, gen. non det.

INCERTÆ SEDIS.

Cœlorhynchus cretaceus, Dixon.
* *Ancistrodon*, sp.

The following names applied to vertebrate fossils from the English Chalk, are here regarded as synonyms. It has been thought most convenient to arrange these in a separate alphabetical list, the accepted determination of each being added, and thus showing precisely the fate of many of the names which still survive in collections.

SYNONYMS.

Acrodontosaurus Gardneri, Mason.—*Pachyrhizodus Gardneri.*
Acrodus rugosus, Agassiz.—*Drepanephorus canaliculatus* (*?*).
,, *cretaceus*, Dixon.— ,, ,,
Acrotemnus faba, Agassiz.—*Cœlodus faba.*
Amia ? lewesiensis, Mantell.—*Macropoma Mantelli.*
† *Aulodus Agassizi*, Dixon.—*Ptychodus* (*?*) *polygyrus.*
Beryx ornatus, Agassiz.—*Hoplopteryx levesiensis.*
,, *superbus*, Dixon.— ,, *superbus.*
* *Caturus similis*, Agassiz.—Genus non det.
Cestracion canaliculatus, Egerton.—*Drepanephorus canaliculatus.*
Chelone Benstedi, Owen.—*Cimoliochelys Benstedi.*
Cimoliornis diomedeus, Owen.—*Ornithocheirus giganteus.*
* *Corax maximus*, Dixon.—*Corax falcatus.*
Emys Benstedi, Mantell.—*Cimoliochelys Benstedi.*
Enchodus halocyon, Agassiz.—*Enchodus levesiensis.*
Erisichthe Dixoni, Cope.—*Protosphyræna ferox.*
Esox lewesiensis, Mantell.—*Enchodus levesiensis.*
Gyrodus angustus, Agassiz.—*Cœlodus angustus.*
† ,, *conicus*, Dixon.—*Gyrodus cretaceus.*
Hypsodon lewesiensis, Agassiz.—*Pachyrhizodus Gardneri.*
Portheus Mantelli.
Portheus sp. ind.
,, *minor*, Dixon.—*Ichthyodectes minor.*
* *Lamna acuminata*, Agassiz.—*Oxyrhina Mantelli.*
Leiodon anceps, Owen.—*Mosasaurus anceps.*
Microdon nuchalis, Dixon.—*Platax nuchalis.*
Mosasaurus stenodon, Charlesworth.—*Mosasaurus anceps.*
,, *gracilis*, Owen.—*Pachyrhizodus gracilis.*
Muræna ? lewesiensis, Mantell.—Worm-burrows.
* *Orthagoriscus* sp., Dixon.—Chelonian dentary bone.
Osteornis diomedeus, Gervais.—*Ornithocheirus giganteus.*
* *Phacodus punctatus*, Dixon.—Indeterminable Pycnodont Teeth.

* *Polyptychodon continuus*, Owen.—*Polyptychodon interruptus*.
Pterodactylus compressirostris, Owen.—*Ornithocheirus compressirostris*.
,, *conirostris*, Owen.— ,, *giganteus*.
,, *Cuvieri*, Bowerbank.— ,, *Cuvieri*.
,, *giganteus*, Bowerbank.— ,, *giganteus*.
Ptychodus arcuatus, Agassiz.—*Protosphyræna* sp.
,, *articulatus*, Agassiz.—(?) ,,
,, *altior*, Agassiz.—*Ptychodus mammillaris*.
,, ,, Dixon.— ,, *rugosus*.
,, *depressus*, Dixon.— ,, *decurrens*.
,, *gibberulus*, Agassiz.—*Protosphyræna* sp.
,, *paucisulcatus*, Dixon.—*Ptychodus latissimus*.
,, *spectabilis*, Agassiz.—*Protosphyræna* sp.
Pycnodus cretaceus, Agassiz.—*Cœlodus cretaceus*.
,, *parallelus*, Dixon.— ,, *parallelus*.
Rhaphiosaurus lucius, Owen.—*Rhaphiosaurus subulidens*.
Salmo lewesiensis, Mantell.—*Osmeroides levesiensis*.
Saurocephalus lanciformis, Agassiz (*non* Harlan).—*Protosphyræna ferox*.
Saurodon Leanus, Agassiz (*non* Hays).—*Cimolichthys levesiensis*.
Selache Davisi, Hasse.—*Ptychodus* sp. ind.
Spinax major, Agassiz.—*Drepanephorus canaliculatus*.
* *Strophodus asper*, Agassiz.—Fragment of Crustacean.
Tetrapterus minor, Agassiz.—*Protosphyræna minor*.
* *Tomognathus leiodus*, Dixon.—*Tomognathus mordax*.
* *Xiphias Dixoni*, Leidy.—*Protosphyræna ferox*.
Zeus lewesiensis, Mantell.—*Hoplopteryx levesiensis*.

V.—General Key to the Known Vertebrate Fossils of the English Chalk.

Bones.

(i) Delicate, squamous.	Fishes; Chelonian.
(ii) Hollow, thin-walled.	Pterodactyles.
(iii) More massive.	Dinosaurian; Mosasaurian; Plesiosaurian; Ichthyosaurian; Chelonian; Snout of *Protosphyræna*.

TEETH.

(i) With base having appearance of no connection with sockets or bone. Selachian.

  (A) Depressed, crushing. *Ptychodus; Drepanephorus; Acrodus;* some *Hybodus* and *Synechodus.*

  (B) Conical.

    (a) Much compressed, edge serrated in large specimens.
    Corax.

    (b) Somewhat thicker, not serrated; rarely traces of lateral denticles.
    Oxyrhina, Squatina.

    (c) Similar, with large lateral denticles.
    Otodus.

    (d) Long and cylindrical, with lateral denticles.
    Odontaspis; Scylliodus; some *Hybodus.*

    (e) Series of compressed cones on one base.
    Notidanus.

(ii) Fixed in sockets or attached to bone.

  (A) Flattened, crushing. *Gyrodus; Cœlodus; Belonostomus; Plethodus.*

  (B) Conical, with sharp edges only in part.

    (a) With short base, or none.
    Dolichosaurus; Coniosaurus; Cimolichthys; Pomognathus; Tomognathus; Portheus; Ichthyodectes; Belonostomus.

    (b) With comparatively large base.
    Polyptychodon; Plesiosaurus; Mosasaurus; Pachyrhizodus; Stratodus.

  (C) Much laterally compressed, with sharp edges.

    (a) Edges smooth.
    Ornithocheirus; Protosphyræna; Daptinus; Ancistrodon.

    (b) Edges dentated. *Acanthopholis.*

  (D) Portions of bone with dentinal areas. Chimæroid Fishes.

SCUTES AND SCALES.

(i) Arrow-head-shaped.
Dercetis; Plinthophorus.

(ii) Cycloid scales.

Osmeroides; *Acrognathus*; *Aulolepis*; *Pachyrhizodus*; *Cladocyclus*; *Calamopleurus*; *Berycopsis*.

(iii) Ctenoid scales.

Beryx; *Hoplopteryx*; *Stenostoma*; *Homonotus*.

(iv) Ganoid scales.

(A) Rhombic.

Lophiostomus; *Neorhombolepis*; *Belonostomus*; *Gyrodus*; *Cœlodus*; *Prionolepis*.

(B) Round and much ornamented.

Macropoma.

SPINES.

(i) Round, ribbed.

Cœlorhynchus.

(ii) Laterally-compressed, smooth.

Drepanephorus.

EXPLANATION OF PLATE I.

FIG. 1.—*Neorhombolepis excelsus*, A. S. Woodw., nat. size; Lower Chalk, Upper Halling, Kent. *op.* operculum. *p.* pectoral fin. *p. cl.* post-clavicular scales. *S. op.* suboperculum. (B.M., No. 43,077.)

FIG. 2.—Scales of the so-called *Lepidotus punctatus*, Agassiz MS., nat. size; Blue Bell Hill, Burham, Kent. Collection of Mr. S. J. Hawkins, F.G.S.

FIG. 3.—Portion of dentition of *Stratodus anglicus*, A. S. Woodw., nat. size; Glynde, Sussex. *3a.* Section of tooth. (B.M., No. 49,906.)

FIG. 4.—Anterior portion of left dentary bone of ditto, showing bases of two series of teeth, nat. size; Lower Chalk, Southeram, near Lewes. The depth of the bone is not clearly indicated, owing to the aspect shown being half-superior, half-lateral. (B.M., No. 49,780.)

FIG. 5.—Skull and mandible of *Enchodus levesiensis*, Mant. sp., side view, nat. size; Lewes. *d.* Dentary bone. *mx.* maxilla. *pmx.* premaxilla. (B.M., No. P. 5,415.)

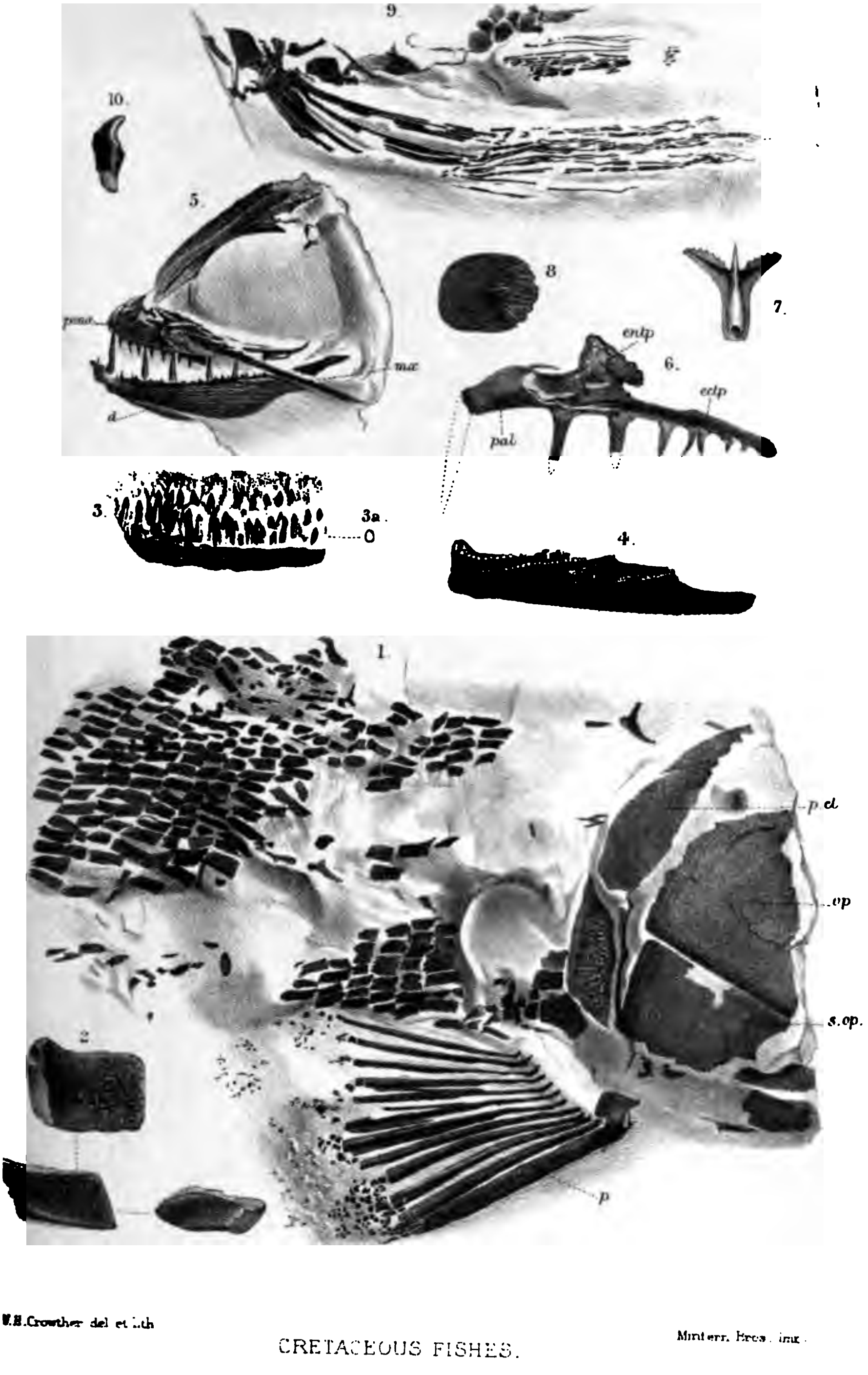
FIG. 6.—Palato-pterygoid arcade of ditto, nat. size; Lewes. *ectp.* ectopterygoid. *entp.* entopterygoid. *pal.* palatine. (B.M., No. P. 5,416.)

FIG. 7.—Scute of "lateral line" of *Dercetis elongatus*, Agass., eight times nat. size; Norfolk. Collection of Dr. George J. Hinde, F.G.S.

FIG. 8.—Scale of *Pachyrhizodus*, nat. size; Sussex. (B.M., No. P. 1,808.)

FIG. 9.—Pelvic fin, and fragment of ditto, of *Beryx radians*, Agass., nat. size; Kent. (B.M., No. 39,429.)

FIG. 10.—Tooth of *Ancistrodon*, nat. size; Lewes. (B.M., No. 49,956.)



W.H. Crowther del et lith

CRETACEOUS FISHES.

Mintern Bros. imp.

ORDINARY MEETING.

FRIDAY, JANUARY 6TH, 1888.

F. W. **RUDLER**, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—G. E. Blanch, B.A.; A. Hotson; and F. Rayner.

Mr. S. H. Needham and Mr. Horace W. Monckton were elected Auditors for the past year's accounts.

The following paper was then read:—'On the Occurrence of Gold in Wales,' by Mr. T. A. **READWIN**, F.G.S.

There were exhibited:—

Gold and silver coins of Welsh metal, exhibited by Mr. T. A. **READWIN**.

Quartz with gold from Wales, exhibited by Mr. **MORGAN**.

Gold-ore from Nova Scotia, and Malachite and Chessylite interstratified, from Arizona, exhibited by Mr. B. B. **WOODWARD**, F.G.S.

Palæolithic implements found in valley-gravels at Clerkenwell, Crayford, and Barton (Hants) during 1887, exhibited by Mr. W. J. L. **ABBOTT**.

ON THE OCCURRENCE OF GOLD IN WALES.

By T. A. **READWIN**, F.G.S.

(Abridged.)

The occurrence of gold in Britain has been known to geologists for rather less than half-a-century; yet it is certain that the well-to-do of the ancient Britons indulged rather extravagantly in gold ornaments, which must have been made of British gold. It is more than probable that the Romans discovered gold in Wales, and wrought it, for there are evidences of Roman mine-works where gold must have been the principal, if not the sole, object of search.

One of the most remarkable of these is in South Wales, on the banks of the Cothy, at Gogofau, near Pumpsaint, Caermarthenshire. Here a quartz-lode has been worked "open to the day," and a level has been driven nearly 200 feet through slaty rock.

The gold-field of North Wales commanding special attention is the mountainous district of Merionethshire, having an area of fifty or more square miles, and, for the most part, being well-known to tourists on account of its picturesque scenery.

As to the mode of occurrence of gold generally, I will quote the opinion of Sir Roderick Murchison. In his 'Siluria' he wrote to the effect that the most usual position of gold is in quartzose veinstones that traverse altered Palæozoic slates, frequently near their junction with eruptive rocks, whether of igneous or of aqueous origin; also, that "the stratified rocks of the highest antiquity, such as the oldest gneiss or quartz rocks, have seldom borne gold; but the sedimentary accumulations which followed, or the Silurian, Devonian, and Carboniferous (particularly the first of these three), have been the deposits which, in the tracts where they have undergone a change of structure, by the influence of igneous agency or other causes, have been the chief sources whence gold has been derived." This has since proved, I believe, to be almost universally the case.

Prof. [now Sir Andrew] Ramsay, in 1854,* refers to the gold-bearing district of Merionethshire thus: "A small part of this area [about twenty square miles] has for some years been distinguished by discoveries of gold, of more or less importance. Its geological relations are as follows:—On the north and west of the lower part of the River Mawddach lie the lowerpart of the Lingula-flags and the Cambrian rocks. The latter consist of the coarse, thick-bedded, greenish-grey grits of Barmouth and Harlech. Their upper boundary is marked by a sinuous line which strikes in a north-easterly direction from Barmouth to Rhaiadr-Mawddach, and from thence trends northerly, a little east of Trawsfynydd, to the turnpike road about a mile south of Ffestiniog. The line then strikes south-west to Morfa Harlech, on the coast of Cardigan Bay. These grits are overlaid by that part of the Lower Silurian rocks known as the Lingula-flags, which here consist mostly of blue slaty beds, generally more or less arenaceous, and partly interstratified with courses of sandstone. A well-marked portion of the series, composed of rusty ferruginous slate, occupies part of the cliffs of Moel Cynwch that overhang Dol-fawr on the Mawddach. Both Cambrian and Silurian rocks have been penetrated by numerous greenstone-dykes. Many of them are of a light grey colour and highly calcareous. Others assume the colour and texture of ordinary greenstone. Some of them are magnetic. Among the Cambrian sandstones they run in all directions, sometimes with, but more generally across, the strike. In the Silurian region they more usually run more or less parallel with the lines of bedding. In the hard and solid Cambrian sandstones, the fractures into which they were injected were capricious and irregular; while in the Silurian shales they have more frequently been intruded between the beds. Some of them fill cracks which pass into lines of lode. . . . Several lodes occur in this country in the neighbourhood of Dol-y-frwynog and Cwm Eisen. The gold at Cwm Eisen was discovered in 1843, by Mr. Arthur Dean, who, in a paper published in the 'Report of the British Association for 1844,' stated that 'a complete system of auriferous veins exists throughout the whole of the Snowdonian or Lower Silurian formations of North Wales.' Recent events [1854], would seem in a slight degree to verify this bold assertion. . . . The whole of these [lodes] lie either in the Lingula-flags, or in the beds immediately adjoining above or below; and they lend additional evidence to the views that have often been promulgated by Sir Roderick Murchison."

---

* 'Quart. Journ. Geol. Soc.,' Vol. x, p. 242.

I make no apology for quoting so much, for I can arrange no words that will describe the facts so briefly and clearly as these. I may add that there are hundreds of quartz-lodes in this district of all widths up to 66 feet, cropping out at the surface, and all of them are more or less auriferous.

Notwithstanding all that has been said and written about this district, I must frankly acknowledge that geologically it remains, to my comprehension, pretty much as Mr. Salter, the expert fault-finder, left it, "a perfect puzzle." I will briefly state that the hand-specimens I have collected show:—Black, micaceous, and talcose schists; black and green shales; hard dark-grey, felspathic, ashy, and cindery-looking uncleavable slates (Lower Silurian of the Survey); black slates (Upper Cambrian of the Survey); felspathic and "trappean" grits; hard, coarse sandstone; rough schists, shales, and slates (Lower Cambrian of the Survey); portions of felspathic-lava beds; striped cinder-beds, both chloritic and mixed with grit and sandstone; spotted, blotched, felspathic, and interbedded "trap-rocks;" bits of ashy beds; yellow clay; "elvan," "flookan," and quartzite; the usual "intrusive greenstones" of the Survey, which are green, grey, and reddish in colour, often very coarse-grained, prominently quartzose, and prominently hornblendic; also diabase and diorite, and David Forbes's "magnificent uralite porphyry."

The minerals include compact and crystallized barytes, calcite (sparsely), orthoclase, ripidolite, black hornblende, white scaly mica; white, yellow, ferruginous, calciferous, auriferous, plumbiferous, zinciferous, cupriferous, and pyritous quartz, with the cherty or hornstone variety abounding, which is often powdered, so to speak, with extremely fine gold, all of which is so light that it will float on water; talc also occasionally, and uralite; native gold, native silver, native antimony, native copper, galena, copper pyrites, iron pyrites, mispickel, marcasite, rhodochrosite, tetrahedrite, polytelite (of D. Forbes), pyromorphite, blende, stibnite, senarmontite, berthierite, aphthonite (of Glocker), earthy malachite, platinum, titanoferrite (of D. Forbes), tetradymite, magnetite, bismuthine, &c. Gold is found *in situ* in the metallic state, of a very pale yellow colour. As yet it has not been found in anything approaching geometric forms of crystallization. Generally the gold is disseminated in whitish crystalline quartz or in hornstone, in a state of division so minute as to be scarcely discernible by the aid of a powerful lens. Occasionally this precious metal is found something like what Sir R. Murchison characterized as "crystallized twigs." This gold, as found, nearly answers to Pliny's "electrum," containing 10 to 15, or more, per cent. of combined silver.

The modes of occurrence of gold in this district are very varied. It occurs visibly, and sometimes extremely richly, in slate, shale, schist, barytes, quartz, and hornstone; also in galena, blende, copper pyrites, iron pyrites, marcasite and mispickel, tetradymite, tetrahedrite, uralite, titanoferrite, bismuthine, stibnite, and rutile. It occurs in the Mawddach and Cain Rivers, in scales and pepitas, along with iridosmine and bits of platinum, titanoferrite, galena, pyrites, &c. It is always more or less combined with silver in the sulphides, arsenides, &c., and sometimes with copper, as at Clogau. It has been frequently found in fern-roots by the banks of the Mawddach, and, it unfortunately must be added, arsenolite, cerussite, and pyromorphite occasionally occur, which are the antagonists of nearly all the processes of gold-getting by means of quicksilver. This, however, is to a great extent now remediable. I should detain you too long if I described certain proofs I have observed during the last ten or twelve years, of what I still incline to call spontaneous gold-growth, by which I mean exudations or emanations of gold from the surface of specimens of quartz, pyrites, galena, blende, and other minerals of the Mawddach valley in question.

I now fearlessly assert that the numerous quartz lodes of the Merioneth gold-field are generally auriferous. My confidence is based on the fact that, since I first became interested in the Welsh gold question, I have made myself, superintended the making of, or paid for the making (by the first men of the day) of more than 1,600 assays and amalgamation operations upon mixed minerals of this lovely valley for the purpose of ascertaining their commercial value when taken through and through for gold and silver. Of these I made over a thousand trials for gold especially, and only 14 of them gave of gold *nil;* 140 trials gave traces of gold to under 3 dwts. per ton; 48, 3 dwts. and under 5 dwts.; 133, 5 dwts. and under 10 dwts.; 64, 10 dwts. and under 1 oz.; 129, 1 oz. and under 2 ozs.; 74, 2 ozs. and under 3 ozs.; 189, 3 ozs. and under 5 ozs.; 92, 5 ozs. and under 10 ozs.; 40, 10 ozs. and under 20 ozs.; 22, 20 ozs. and under 50 ozs.; 15, 50 ozs. and under 100 ozs.; 11, 100 ozs. and under 200 ozs.; 17, 200 ozs. and under 500 ozs.; 2, 500 ozs. and under 1,000 ozs.; 1, 1,000 ozs. and under 2,000 ozs.; 3, 2,000 ozs. and under 5,000 ozs.; 5, 5,000 ozs. and under 10,000 ozs.; 1, 10,000 ozs. and under 20,000 ozs.

Since these statistics were published in the 'Mining Journal' in 1882, I made, up to June, 1884, 22 trials for gold of the Gwynfynydd lode-stuff, extending over 53¼ tons, which resulted in 44 ozs. 10½ dwts. of gold, exclusive of rich specimens reserved. Of the 22 trials, 3 resulted in under 5 dwts. of gold to the ton of 20 cwts.; 6 between 5 dwts. and 10 dwts.; 6 between 10 dwts. and 1 oz.; 1 between 2 ozs. and 3 ozs.; 1 between 5 ozs. and 10 ozs.; 2 between 10 ozs. and 20 ozs.; 3 between 50 ozs. and 100 ozs.; 1 just at the rate of 22,000 ozs; another exactly at the rate of 35,840 ozs. to the ton, being all electrum, and weighing 1 oz. troy. I may add that at the Gwynfynydd Mine up to June, 1884, I had made altogether 78 trials, and obtained 113½ ozs. of gold, being an average of 1 oz. 11 dwts. 13 grs. to the ton of ore.

That some of the mineral now being produced from this mine is of marvellous beauty and interest cannot be questioned. I am enabled to place on view this evening specimens which will speak very plainly for themselves. Some of them contain gold very heavily. Their real value, however, consists, in my opinion, not in whether they give hopes of vast riches being taken out of that mine in particular, but in whether the whole district can be converted into a field of active and prosperous industry.

Gold has been found at the following mines :—Berthllwydd, Cambrian, Cae Mawr, Castell Carn Dochan, Cefncoch, Cefndeuddwr, Clogau, Cwmheisian, Dolclochydd, Dolfrwynog, Ganllwydd, Garn, Garth, Garthgell, Glasdir, Gwynfynydd, Moel Ispri, Prince of Wales, Tyddynglwadis, and Vigra. Five of these mines only have been tested on what may be called a working scale; and from these, 12,137 tons yielded to owners 14,667 ounces of gold, *i.e.* an average of 1¼ ounces to the ton. To mention one particular instance of gold-yield, I may state, on the authority of the Home Office, that from the Vigra and Clogau mines alone 11,576¼ tons of stone yielded 16,468 ozs. 18 dwts. 8 grs. of gold, which was sold to the Bank of England (chiefly) for £62,849 0s. 6d. Upon this sum one-twelfth in value was then paid to the Crown, as the mineral rights of this property are totally vested in the Crown. The royalty payable at the present time has been reduced to one-fifteenth, and will presently, probably, be reduced to one-twentieth or less. The actual royalty paid to the Crown was £5,015 13s. 9d., as I learn from information courteously given me by the Hon. James Kenneth Howard, the Commissioner in charge of the Land Revenue at the Office of Woods and Forests. In the matter of fire-assays, as applied to gold ores for the purpose of testing their commercial value in bulk, possibly I have a lower estimate of their utility than anybody present. Taking, for example, the 4,000 tons of auriferous stone, said to have been raised recently at the Gwynfynydd Mine, estimated to contain an average of 2 ounces of gold to the ton, I am heterodox enough to disbelieve the possibility of what is called "fair sampling" any such quantity, or the 4,000th part of any such quantity. Whoever attempts fair sampling has to start with the assumption that every particle of gold is of equal size and weight, and, moreover, equidistant, a state of things that has never been found in nature, has never been accomplished by art, and never can be.

In conclusion allow me to express my regret that the public have got into such a state of unrest about Welsh gold. But, notwithstanding recent exaggerations as to the gold at Gwynfynydd, there certainly exists plenty of it, and I believe that Old Vigra and Clogau, the Prince of Wales, Cefncoch, Berthllwydd, Cefndeuddwr, and other mines are destined to yield on large quantities nearly an ounce of gold to the ton of mineral.

ANNUAL GENERAL MEETING.

FRIDAY, FEBRUARY 3RD, 1888.

F. W. RUDLER, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

Messrs. W. J. Abbott and William White were appointed scrutineers for the ballot.

The following report of the Council for the year 1887 was read :—

The numerical strength of the Association on the 31st December last showed an increase nearly twice as great as that recorded on the corresponding date of the previous year, and was as follows :—

Honorary Members	14
Ordinary Members :—	
a Life Members (Compounded)	126
b Old Country Members (5s. Annual Subscription)	13
c Other Members (10s. Annual Subscription) ...	361
Total	514

During the year 58 new Members were elected. The Council regret that the Association lost four Members by death :—Mr. A. Champernowne, the Rev. W. Downes, Mr. S. Galloway, and Dr. F. V. Hayden.

Mr. A. Champernowne, though he had been but a short time one of our Members, was well known to all students of Devonshire geology, whilst those Members of the Association who attended the excursion to South Devon in July, 1884, have special reason to call to mind our kind and genial host and director.

Mr. Champernowne was the eldest son of Henry Champernowne, of Dartington, and was born 19th March, 1839. Educated at Eton and at Trinity College, Cambridge, he soon became interested in geology, especially that of his native Devonian rocks, which he studied with the most thorough and minute care, both palæontologically and petrologically, not only in Devonshire, but also on the Continent. He died on the 22nd May, 1887, having caught a chill on his return home from a meeting of the Geological Society.

Dr. Ferdinand Vandeveer Hayden (born 7th September, 1829, died December 22nd, 1887), who was elected an Honorary Member

As regards its financial position, the Association is in a very satisfactory condition. There is a considerable balance in hand, and the invested capital at its present value now covers the whole of the composition fees received from existing Life Members. In the last Annual Report your Council recommended that the sum of £10 should be invested in order to bring up the funded property to the amount received from the Life Members, whose addresses were known, and who only were receiving the benefits of membership. Early in the year, before steps were taken to carry this out, ten Members compounded, increasing by 50 guineas the amount to be invested. It was then thought advisable to sell the £547 4s. 8d. held in Consols, and, adding 60 guineas to the proceeds of the sale, to make a more remunerative investment. Nottingham Corporation 3 per cent. Stock was eventually selected, the Consols were sold after receipt of the July dividend at 101⅜ per cent., yielding £554 15s. 2d., and with this and £63 there was purchased £691 4s. Nottingham 3 per cent. Stock at 89¼ per cent. The gain to the Association in interest by this transaction is a little under ½ per cent., and a further advantage has accrued, for, since it was carried out, the Nottingham Stock has gone up 6½ per cent., the investment being now worth about £45 more than when the purchase was made, and thus at its present value covering the contributions of the whole of the Life Members, known and unknown, including two composition fees received since July. Although the greater portion of the balance in hand on revenue account will be required to meet expenditure on publications which should have appeared in 1887, the receipts in 1888 may be confidently anticipated to suffice for the ordinary expenditure of the year. (For Balance-sheet see next page.)

Since our last annual meeting three numbers of the 'Proceedings' have been issued to Members, viz., No. 8, of Vol. ix, and Nos. 1, 2, of Vol. x, 178 pages in all, illustrated by 12 engravings. Three more numbers of Vol. x, which have been unavoidably delayed, are now nearly ready and will be issued shortly. As the current year will witness the completion of the first decade of volumes of our 'Proceedings' it is proposed to issue a general index to the whole, which is now in preparation, and it is hoped that by the adoption of a slightly different method of publication the issuing of papers and reports may then be rendered more expeditious.

Your Council have much pleasure in announcing that Mr. T. V.

of this Association in 1879, will ever be remembered by geologists in connection with the United States Geological and Geographical Survey of the Territories, of which he was the head. In the spring of the same year in which he received his degree in medicine (1853) Dr. Hayden was sent by Prof. James Hall, of Albany, with Mr. F. B. Meek to visit the Bad Lands of White River and make collections of the Cretaceous and Tertiary fossils of that region. This was the beginning of his explorations in the West, which continued with but little interruption for more than thirty years. The collections made during this and the two following years attracted the attention of the officers of the Smithsonian Institution, and he was employed by the Government to report upon the region he had explored. He was next attached as geologist to Lieut. Warren's staff, which was engaged in making a reconnaissance of the North West. In 1859 he was appointed naturalist and surgeon to Captain W. F. Raynolds' expedition for the exploration of the Yellowstone and Missouri Rivers, till the outbreak of the civil war, through which he went as surgeon to the volunteers. Retiring from the army in 1865 he was then elected Professor of Geology and Mineralogy in the University of Pennsylvania, a position he held until 1872. The summer of 1866 found him again exploring the Bad Lands of Dakota; whilst from 1867 to 1879 all his energies were devoted to the success of that grand survey of the territories, whose most valuable and voluminous publications, including the magnificent atlas of Colorado, we, through his kindness, are fortunate enough to possess. The reservation of the Yellowstone National Park as a pleasure ground for the people of the United States, an idea which originated with Dr. Hayden, was one of the results of his surveys, and the law setting it apart was prepared under his direction. When in 1879 the survey of the territories was disbanded, Dr. Hayden received an appointment on the newly-organized United States Geological Survey, and for about three years was engaged in completing the business of his former charge and in preparing the final reports of the results obtained when, his health failing, he resumed field work, this time in Montana. In 1886 he was unable to continue his work, and finally resigning, closed an honourable connection with his Government that included 28 years of actual service as naturalist, surgeon, and geologist.*

---

* 'Science,' xi, pp. 1-2.

As regards its financial position, the Association is in a very satisfactory condition. There is a considerable balance in hand, and the invested capital at its present value now covers the whole of the composition fees received from existing Life Members. In the last Annual Report your Council recommended that the sum of £10 should be invested in order to bring up the funded property to the amount received from the Life Members, whose addresses were known, and who only were receiving the benefits of membership. Early in the year, before steps were taken to carry this out, ten Members compounded, increasing by 50 guineas the amount to be invested. It was then thought advisable to sell the £547 4s. 8d. held in Consols, and, adding 60 guineas to the proceeds of the sale, to make a more remunerative investment. Nottingham Corporation 3 per cent. Stock was eventually selected, the Consols were sold after receipt of the July dividend at 101⅜ per cent., yielding £554 15s. 2d., and with this and £63 there was purchased £691 4s. Nottingham 3 per cent. Stock at 89¼ per cent. The gain to the Association in interest by this transaction is a little under ½ per cent., and a further advantage has accrued, for, since it was carried out, the Nottingham Stock has gone up 6½ per cent., the investment being now worth about £45 more than when the purchase was made, and thus at its present value covering the contributions of the whole of the Life Members, known and unknown, including two composition fees received since July. Although the greater portion of the balance in hand on revenue account will be required to meet expenditure on publications which should have appeared in 1887, the receipts in 1888 may be confidently anticipated to suffice for the ordinary expenditure of the year. (For Balance-sheet see next page.)

Since our last annual meeting three numbers of the 'Proceedings' have been issued to Members, viz., No. 8, of Vol. ix, and Nos. 1, 2, of Vol. x, 178 pages in all, illustrated by 12 engravings. Three more numbers of Vol. x, which have been unavoidably delayed, are now nearly ready and will be issued shortly. As the current year will witness the completion of the first decade of volumes of our 'Proceedings' it is proposed to issue a general index to the whole, which is now in preparation, and it is hoped that by the adoption of a slightly different method of publication the issuing of papers and reports may then be rendered more expeditious.

Your Council have much pleasure in announcing that Mr. T. V.

GEOLOGISTS' ASSOCIATION.

Income and Expenditure for the Year ending 31st December, 1887.

Dr.

	£	s.	d.
To Balance from last Account	32	17	6
„ Life Compositions	63	0	0
„ Admission Fees	28	0	0
„ Annual Subscriptions (£160 10s., less 10s. Subscription returned)	160	0	0
„ Dividends on £547 4s. 8d. Consols	15	18	2
„ „ £691 4s. Nottingham Corporation Three per cent. Stock	10	1	4
„ Sale of Publications	17	12	6
„ Advertisements	3	10	6
„ Sale of £547 4s. 8d. Consols at 101⅜ per cent.	554	15	2
	£885	15	2

Cr.

	£	s.	d.
By Printing 'Proceedings'	62	8	3
„ „ 'Geology of Cornwall'	6	10	0
„ „ Monthly Circulars	18	0	6
„ Illustrating 'Proceedings' and Circulars ...	6	6	0
„ Miscellaneous Printing...	15	4	0
„ Postages	35	19	9
„ Addressing	8	9	0
„ Library	15	14	9
„ Fire Insurance for 1888	1	17	6
„ Stationery	1	10	7
„ Attendance, Gas, &c., at Evening Meetings	12	4	6
„ Miscellaneous Expenses	1	9	6
„ Purchase of £691 4s. Nottingham Corporation Three per cent. Stock at 89¼ per cent.	616	17	10
„ Brokers' Commission	0	17	4
„ Balance in Bank of England	82	5	8
	£885	15	2

We have this day examined the Accounts of the Treasurer of the Geologists' Association, and we find the above Statement to be correct.

(Signed) S. H. NEEDHAM, HORACE W. MONCKTON, } **Auditors.**

19th January, 1888.

Holmes has recently taken in charge the long projected volume which should contain a summary of our Excursions. Mr. Holmes' great knowledge of British geology is a guarantee of its ultimate success.

The Library, which continues to increase not only by presentations, but also by valuable exchanges, has for some time past been spreading over a constantly increasing space, so that your Council found it both desirable and necessary to have the books rearranged; those most frequently in requisition being placed in the bookcase in the College Library, where they are more readily accessible at the evening meetings. The list of these books appended to the 'List of Members,' issued in November, will, it is hoped, be of great service to those who avail themselves of the privilege of borrowing from the Library, and well repay the cost incurred.

Your Council, however, would remind Members that the question of facilitating the circulation of the volumes, and thus rendering the collection of the greatest service, depends on the punctuality shown in returning books as stipulated by the Library regulations, and therefore rests with the individual borrowers.

Your thanks are due to Mr. E. Litchfield, who has resumed the office of Assistant-Librarian, and placed his services at your disposal on the nights of the evening meetings.

The following is the list of papers read at the evening meetings :—

'On Crinoids and Blastoids,' by Dr. P. H. CARPENTER, F.R.S., &c.

'On the recent Volcanic Outburst in New Zealand,' by W. LANT CARPENTER, B.A., B.Sc.

'A revision of our Lower Eocenes,' by G. F. HARRIS, F.G.S., &c.

'On the Metamorphosis of Basic Igneous Rocks,' by J. J. HARRIS TEALL, M.A., F.G.S., &c., with Lime-Light Illustrations.

'On the Unmaking of Flints,' by Prof. J. W. JUDD, F.R.S., Pres. G.S., &c.

'On the Formation of Agates,' by W. J. ABBOTT.

'On the Formation of Rounded Flint Pebbles,' by J. LOGAN LOBLEY, F.G.S.

'On the Geology of Cornwall, with special reference to the Long Excursion,' by J. H. COLLINS, F.G.S., &c.

'On the Deposition of the London Clay,' by J. STARKIE GARDNER, F.G.S., &c.

'Fifty Years' Progress in British Geology,' by F. W. RUDLER, F.G.S., Hon. Sec. Anthrop. Inst.

'The Vertebrate Fossils of the English Chalk,' by A. SMITH WOODWARD, F.G.S., Assist. Geol. Dept. British Museum (Natural History).

The practice of exhibiting objects of geological interest at our evening meetings has been continued with success, but is capable of yet further extension, and hopes are entertained that in the coming year the exhibits will be both more numerous, and cover a wider field.

Subjoined is a list of the Museums, Geological collections, &c., visited during 1887:—

British Museum (Natural History), on March 12th, when Dr. Henry Woodward, F.R.S., conducted the Members through the Fossil Reptile Gallery and the 'Type Collections,' on which last he delivered a brief address.

Pottery Works of Messrs. Doulton and Co., Lambeth, on March 30th, when Sir Henry Doulton described to the Members present the processes of manufacture, after which they were conducted over the works.

Hartley Institution Museum, Southampton, on April 8th, when Mr. T. W. Shore, the Executive Officer, described the collection.

Brighton Museum, on April 11th, when Mr. E. Crane, F.G.S., and Mr. H. Willett, F.G.S., conducted the Members over the building, and explained the contents.

Corinium Museum, Cirencester, on May 30th.

Royal Agricultural College, Cirencester, on May 30th, when, by the kind permission of the Principal, the Museum with its geological collections, the Biological Laboratory, and the Botanic Gardens were open for the inspection of the Members.

Mr. J. Allen Brown, F.G.S., on the occasion of the excursion to Ealing, June 18th, afforded those present an opportunity of inspecting his collection of Flint and other Implements, &c.

Museum of the Royal Institution of Cornwall, at Truro, on August 8th, over which those who took part in the Long Excursion were conducted by Major E. Parkyn, the Hon. Sec.

Museum of the Royal Geological Society of Cornwall, at Penzance, on August 10th, when Mr. W. Brown Millett and Mr. W. Ambrose Taylor explained the collections to the party.

Mr. Charles C. Ross, of Penzance, on August 10th, allowed the Members the privilege of inspecting his magnificent collection of Minerals (which included the historic collection of Cornish minerals formed by Mr. Joseph Carne), and moreover extended to them his hospitality.

The following is a list of the Excursions made during the past year, detailed reports of which will be found in the number of the 'Proceedings' for November, 1887:—

To Southampton, on April 8th and 9th, under the direction of W. Whitaker.

To Brighton, Newhaven, &c., on Easter Monday and Tuesday, April 11th and 12th, under the direction of Henry Willett, F.G.S., and W. Topley, F.G.S.

To Whetstone and Finchley, on April 23rd, under the direction of J. G. Goodchild, F.G.S., and H. B. Woodward, F.G.S.

To the Brent Valley and Hampstead, on May 7th, in association with the Middlesex Natural History Society, under the direction of J. Logan Lobley, F.G.S.

To Merstham, Redhill, and Reigate, on May 21st, in association with the Croydon Microscopical and Natural History Club, under the direction of W. Topley, F.G.S., Geological Survey of England.

To Cirencester and Minchinhampton, on Whitsun Monday and Tuesday, May 30th and 31st, under the direction of Allen Harker, F.L.S., F.G.S., the late Edwin Witchell, F.G.S., and H. B. Woodward, F.G.S.

To Rickmansworth, on June 4th, in association with the Hertfordshire Natural History Society, under the direction of John Hopkinson, F.L.S., F.G.S.

To Aylesbury, on June 11th, under the direction of W. H. Hudleston, M.A., F.R.S.

To the Mount, Ealing, and Horsington Hill, on June 18th, under the direction of J. Allen Brown, F.G.S.

To Gomshall, Netley Heath, and Clandon, on June 25th, under the direction of H. H. French, F.G.S.

To Sudbury (Suffolk), on July 9th, in association with the Essex Field Club, under the direction of Dr. J. S. Holden (of Sudbury) and W. Whitaker, B.A., F.R.S.

To Plumstead and Bostal Heath, on July 16th, under the direction of J. G. Goodchild, F.G.S.

To Sheppey, on July 23rd, under the direction of W. H. Shrubsole, F.G.S.

To Cornwall, from August 8th to 13th, under the direction of the President; William Thomas, Secretary to the Mining Association and Institute of Cornwall; and A. K. Barnett, F.G.S.

The thanks of the Association are especially due to the following gentlemen for assistance and hospitality on these Excursions:—Sir Henry Doulton; Mr. W. W. Whitaker; Mr. T. W. Shore, Southampton; Mr. H. Willett, F.G.S., Miss A. Crane, and Mr. E. Crane, F.G.S., Brighton; Mr. T. W. Danby, M.A., F.G.S.; Prof. A. Harker, F.L.S., Prof. E. Kinch, F.C.S., and the late Mr. E. Witchell, F.G.S., Cirencester; Dr. A. T. Brett, Watford; Mr. J. Allen Brown, F.G.S., Ealing; Mr. W. H. Shrubsole, F.G.S., Sheerness-on-Sea; Mr. W. Thomas, F.G.S., Secretary Mining Association and Institute of Cornwall, Redruth; Mr. A. K. Barnett, F.G.S., Penzance; Rev. W. Jays, M.A., President, Mr. Nicholas Whitley, F.G.S., Vice-President, Major E. Parkyn, Hon. Secretary, and the other members of the Royal Institution of Cornwall; Mr. J. J. Beringer, F.C.S.; Mr.

R. H. Williams, F.G.S., Mr. Stoeker, junior, and Messrs. Lovering and Co., St. Austel; Mr. R. Swain, Clerk of the Works at the Truro Cathedral; Capt. Josiah Thomas, Dolcoath; Capt. Bishop, East Pool; Capt. White, Weal Agar; Capt. Teague, Carn Brea; Capt. Charles Thomas, Cook's Kitchen; Mr. G. L. Bassett and Mr. T. E. Boog, Tehidy; Mr. Fortescue W. Millett, Sir Warington W. and Lady Smyth, Marazion; Mr. G. Brown Millett the Hon. Sec., Mr. Thomas Cornish, Mr. A. Taylor, and the other members of the Royal Cornish Geological Society, Penzance; Messrs. Bolitho, Penzance; Mr. Charles C. and Mrs. Ross, Penzance; Capt. Tilute, Levant Mine, Land's End; Mr. Howard Fox, F.G.S., Falmouth; Mr. E. A. Wünsch, F.G.S., Scorrier.

Your thanks are also due to the Council of University College for the privilege of meeting in their Library, and the accommodation granted for our bookcases as well as the use of the medical Library for our Council meetings; and to the Council of the Quekett Microscopical Club for the loan of their lamps at our soirée last year.

Your Council would take this opportunity to assure the Members that the old and vexed question of applying to the authorities of University College for permission to assemble in some room better adapted for hearing than this Library, has never been lost sight of by them; and that though hitherto its solution has not been, for many reasons, attainable, nevertheless, the increasing success of our meetings, which year by year are better attended, has convinced them that a further attempt should be made. Consequently the matter will be early brought under the notice of your new Council, but it must be borne in mind that increased facilities in one direction not infrequently lead to sacrifices of comfort in another, and that no room in this building is constructed for the purpose of gatherings such as ours.

Your Council have much pleasure in proposing the following gentlemen as Honorary Members of the Association:—Archibald Geikie, LL.D., F.R.S., L. and E., Vice-President of the Geological Society, Director General of the Geological Surveys of the United Kingdom, and 'The Director of the United States Geological Survey,' in consideration not only of their great services to geology, but also of the assistance they have rendered to the Association on various occasions.

The adoption of the Report was proposed by Dr. G. J. Hinde, F.G.S., seconded by Mr. C. J. Alford, F.G.S., and, after discussion, unanimously carried.

The following Officers and Council for the year 1888 were then declared duly elected:—

President:

F. W. Rudler, F.G.S., Hon. Sec. A.I.

Vice-Presidents:

Rev. Prof. T. G. Bonney, LL.D., F.R.S., F.G.S.
Henry Hicks, M.D., F.R.S., F.G.S.
Prof. R. Meldola, F.R.S., F.C.S.
W. Topley, F.G.S., Assoc. Inst. C.E.

Treasurer:

John Hopkinson, F.L.S., F.G.S.,
95, New Bond Street, W., and The Grange, St. Albans.

Secretaries:

J. Foulerton, M.D., F.G.S.,
44, Pembridge Villas, Bayswater, W.

B. B. Woodward, F.G.S., F.R.M.S.,
23, Batoum Gardens, W.

Editor:

Prof. G. S. Boulger, F.L.S., F.G.S.,
18, Ladbroke Grove, W.

Librarian:

John Bradford, F.G.S.,
East Acton, W.

Council:

Rev. Prof. T. G. Bonney, M.A., F.R.S.
Prof. G. S. Boulger, F.L.S., F.G.S.
John Bradford, F.G.S.
Rev. E. S. Dewick, M.A., F.G.S.
John Foulerton, M.D., F.G.S.
H. H. French, F.G.S.
W. B. Gibbs, F.R.A.S.
Henry Hicks, M.D., F.R.S., F.G.S.
T. V. Holmes, F.G.S.
John Hopkinson, F.L.S., F.G.S.
W. H. Hudleston, M.A., F.R.S., Sec.G.S.
J. Logan Lobley, F.G.S., F.R.G.S.
J. Love, F.G.S., F.R.A.S.
Col. C. A. McMahon, F.G.S.
Prof. R. Meldola, F.R.S., F.C.S.
S. H. Needham, F.G.S.
E. T. Newton, F.G.S.
F. W. Rudler, F.G.S., Hon. Sec. A.I.
J. J. H. Teall, M.A., F.G.S.
W. Topley, F.G.S., Assoc. Inst.C.E.
A. Smith Woodward, F.G.S.
B. B. Woodward, F.G.S.

The thanks of the Association were given to the retiring Members of Council, the Auditors and Scrutineers, on the proposal of Rev. D. Fotheringham, seconded by Mr. C. Hansford, and the Annual Meeting then terminated.

ORDINARY MEETING.

Friday, February 3rd, 1888.

F. W. Rudler, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—W. Brindley; C. Fenton; and Dr. W. Hind.

The following Paper was then read:—'On the history and work of the International Geological Congress,' by Mr. W. Topley, F.G.S., A.I.C.E.

There were exhibited:—

Silver and other ores from Mexico and the United States, exhibited by C. J. Alford, F.G.S.

ORDINARY MEETING.

Friday, March 2nd, 1888.

F. W. Rudler, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—G. Greenly; H. R. Hind; T. P. Moody; A. C. Young.

The following Papers were then read:—'Note on the Pleistocene land and fresh-water Mollusca from Barnwell,' by Mr. B. B. Woodward, F.G.S., Secretary.

'On the Evolution of the Cephalopoda,' by Mr. F. A. Bather, B.A., F.G.S.

The latter paper has been withdrawn.

There were exhibited:—

Land and fresh-water Mollusca from the Pleistocene deposit at Barnwell, exhibited by Rev. E. S. Dewick, M.A., F.G.S.

Recent and Fossil Cephalopoda, exhibited by A. H. Foord, F.G.S., and F. A. Bather, B.A., F.G.S.; and Carboniferous Cephalopoda, exhibited by P. Roscoe.

NOTE ON THE PLEISTOCENE LAND AND FRESHWATER MOLLUSCA FROM THE BARNWELL GRAVELS.

BY B. B. WOODWARD, F.G.S.

The first recorded list of shells from the "classical" deposit of gravel at Barnwell was that read before the Cambridge Philosophical Society in 1838 by the Rev. P. B. Brodie, though its publication was delayed till 1844.* From a note appended by Prof. Sedgwick, it would seem that shells were previously found there by Mr. J. Okes, with some bones, but that their identity in age with the latter was not then considered to be proved. Mr. Okes' paper does not appear to have been published; its date, however, would be about 1820 to 1825. Mr. Brodie notes that there were two distinct beds with shells, the uppermost containing *Helix* and *Paludina*, by which last he apparently means *Bythinia*, in great abundance; whilst the lower one was charged with numerous *Pupa*, small *Planorbis*, and some *Clausilia*. The list given is not remarkable for length, and the names being now mostly obsolete, it need not be further considered.

In 1866 (forming part of a paper by Prof. Seeley) there appeared a list by the Rev. E. S. Dewick,† showing a distinct advance in the knowledge of the Molluscan fauna of these gravels. Forty-four species are there chronicled, as against twenty names in the preceding record. To this Mr. Alfred Bell added in 1872‡ eleven more species; whilst in 1878§ Mr. A. J. Jukes-Browne published a list of fifty-eight species, three of which are, however, synonyms.

Three years afterwards Messrs. Penning and Jukes-Browne compiled from the foregoing, and the specimens in the Woodwardian Museum, Cambridge, a catalogue‖ which, in point of length, leaves nothing to be desired; but, unfortunately, as they neither checked the identifications nor struck out the synonyms, their work loses much of the value it would otherwise possess. Some species, too, are included which come from neighbouring deposits, considered by the authors to be of the same age.

---

* 'Trans. Camb. Phil. Soc.,' viii (1844), pp. 138-9.
† 'Quart. Journ. Geol. Soc.,' xxii (1866), p. 477.
‡ 'Proc. Geol. Assoc.,' ii (1872), p. 222.
§ 'The Post Tertiary Deposits of Cambridgeshire,' p. 64.
‖ 'Geol. Surv. Mem.,' Sheet 51, S.W. (1881), pp. 106-7.

Subsequently Prof. McKenny Hughes published a list,* but as this merely enumerates those species which were at that time named in the Woodwardian Museum it may be disregarded, more especially since a complete one is in course of preparation.

Seeking last year to become better acquainted with these shells from Barnwell, I applied to Mr. Dewick to know if his collection were still extant and visible. The response was affirmative, the welcome cordial, and from that moment till now the whole collection, together with the great knowledge of its possessor, has been placed most generously and unreservedly at my disposal. Moreover, during the last few months the beds containing the shells being fortunately well exposed, Mr. Dewick made several excursions to the place, and procured fresh material which yielded to his research yet more species, and so considerably added to the list.

To Mr. H. M. Platnauer, the Curator of the York Museum, and to Mr. E. T. Newton, at the Museum of Practical Geology (Jermyn Street), the writer is indebted for the kind assistance they so readily gave which enabled an examination to be made of the specimens under their respective charges.

With these three collections it had been intended to tabulate that in the Woodwardian Museum, but, as already stated, the specimens there are in more competent hands.†

With the exception of the commoner forms in the York Museum those species here enumerated have been checked by Mr. Dewick, and thus it is hoped that errors in determination have, as far as possible, been avoided.

The total number of species is sixty-seven, of which six are now no longer living in these Islands, viz. :—

Helix fruticum.	*Hydrobia marginata.*
,, *ruderata.*	*Unio litoralis.*
Clausilia pumila.	*Corbicula fluminalis.*

Eighteen names are new to the list. Of these the most important is *Clausilia pumila*, which is now for the first time added to the Pleistocene fauna of Britain; for though this shell is fairly common in the Barnwell deposit, it has hitherto been put down (even by the late Dr. J. G. Jeffreys) as *C. biplicata*.‡ Finding, however, that it differed materially from that species, examples were sent to Dr. Boettger, who has made the genus his special study, and to that eminent authority this opportunity is taken of returning thanks for his kindness in identifying them. He writes: "Ihre fossile Clausilie ist mir ein alter guter Bekannter aus deutschem Pleistocaen, *Clausilia* (*Pirostoma*) *pumila* C. Pfr." Dr. Boettger goes on to say that the specimens in question most resemble a varietal form (by some ranked as a separate species): *C. pumila*, var. *sejuncta*, A. Schm.

---

* 'Geol. Mag.,' 1883, p. 455.

† Since this note was written the paper by Mrs. McKenny Hughes has been published, 'Geol. Mag.,' Dec. iii, Vol. v (1888), pp. 193-207.

‡ 'British Conchology,' Vol. v, p. 161.

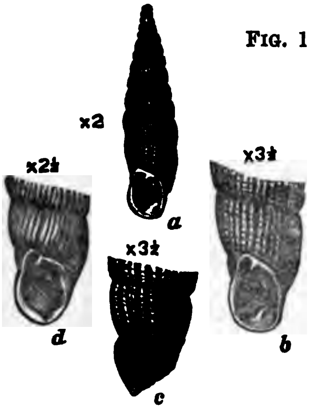


FIG. 1. *a. Clausilia pumila*, Ziegl.

b.——The mouth enlarged to show the sub-columella fold and the spiral striæ on the exterior.

c.——Varietal form in which the external longitudinal markings are wider apart.

[All from the collection of Rev. E. S. Dewick: now in the British Museum (Natural History).]

d. Clausilia biplicata, Mont. Enlarged view of the mouth, showing the absence of the sub-columella fold and the presence of a groove in its place.

This form, according to Kobelt, occurs in Northern Europe, and also in Sweden, but the specimens sent by Dr. Boettger for comparison were obtained at Görlitz, in Silesia, so that on the Continent it has a fairly wide range.

Helix ruderata, in the recent state, occurs in Northern and Central Europe, across to the Caucasus; whilst *H. fruticum* is met with in middle Europe.

It is interesting to note that *Helix obvoluta*, a species common enough in the northern parts of France, and distributed throughout Central Europe, has been found in the gravels of the Cam at Granchester,* beds considered by some to be of the same age as those at Barnwell. This mollusc is now nearly extinct in Britain, being restricted to the Chalk escarpments on the borders of Hants and Sussex; its former extension of range northwards into the Cam Valley is, therefore, noteworthy.

To meet this, an essentially southern form with us, comes *Helix*

---

* This specimen is preserved in the Woodwardian Museum.

		Dewick Coll.	York. Mus.	Mus. Pract. Geol.
†	*Limax agrestis*, Linn.	×		
†	„ *arborum* (?) Bouch.-Chant.	×		
†	„ *lævis* (?) Müll.	×		
	Succinia putris, Linn.	×	×	×
	„ *elegans*, Risso.	×	×	
†	„ *oblonga*, Drap.	?		
	Hyalinia cellaria, Müll.	×		
	„ *nitidula*, Drap.	×	...	×
	„ *radiatula*, Alder	×		
	„ *nitida*, Müll.	×	×	×
†	„ *crystallina*, Müll.	×		
	„ *fulva*, Müll.	×	×	×
	Helix arbustorum, Linn.	×	×	×
	„ *nemoralis*, Linn.	×	×	×
	„ *fruticum*, Müll.	×	×	×
†	„ *caperata*, Mont.	×		
	„ *ericetorum*, Lister	×	×	×
†	„ *lapicida*, Linn.	×		
	„ *hispida*, Linn.	×	×	×
	„ *concinna*, Jeff.	×	×	×
	„ „ reversed var.	×		
†	„ *lamellata*, Jeff.	×		
	„ *pulchella*, Müll.	×	×	×
	„ *rotundata*, Müll.	×		
†	„ *ruderata*, Stud.	×		
	„ *pygmæa*, Drap.*	×	...	×
	Bulimus montanus, Drap.	×	×	×
	„ *obscurus*, Müll.	...	×	
†	*Cochlicopa lubrica*, Müll.	×	×	×
	„ *tridens*, Pult.	×	×	×
†	*Cæcilianella acicula*, Müll.	×		
	Clausilia rugosa, Drap.	×	×	×
†	„ *pumila*, Ziegl.	×	×	×
†	*Balea perversa*, Linn. (young)	?		
	Pupa muscorum, Linn.	×	×	×
	Vertigo antivertigo, Drap.	×		
	„ *Moulinsiana*, Dupuy	×		
	„ *pygmæa*, Drap.	×	...	×
†	„ *angustior*, Jeff.	×	...	×
†	„ *edentula*, Drap.	×		
†	„ *minutissima*, Hartm.	×		

---

* A sinistral monstrosity of this species formerly existed in Rev. E. S. Dewick's collection.

		Dewick Coll.	York Mus.	Mus. Pract. Geol.
	Carychium minimum, Müll.	×	...	×
	Planorbis glaber, Jeff.	×		
†	" *carinatus*, Müll.	×	×	
	" *marginatus*, Drap.	×	×	×
	" *vortex*, Linn.	×	×	×
	" *spirorbis*, Linn.	×	×	×
	" *contortus*, Linn.	×		
	" *fontanus*, Lightfoot	×		
	Limnæa peregra, Müll.	×	×	×
	" *auricularia*, Linn.	×	×	
†	" *stagnalis*, Linn.	×		
	" *palustris*, Müll.	×	×	×
	" *truncatula*, Müll.	×	...	×
	Ancylus lacustris, Linn.	×		
	" *fluviatilis*, Müll.	×	×	×
	Hydrobia marginata, Mich.	×		
	Bythinia tentaculata, Linn.	×	×	×
	Valvata piscinalis, Müll.	×	×	×
	" *cristata*, Müll.	×	×	×
	Unio litoralis, Lam.	×	×	×
	" *pictorum*, Linn.	×	×	×
	Corbicula fluminalis, Müll.	×	×	×
	Sphærium corneum, Linn.	×	×	×
	" *lacustre*, Müll.	...	×	
	Pisidium amnicum, Müll.	×	×	×
	" *fontinale*, Drap. and vars.	×	×	×
	" *pusillum*, Gmel.	×		

lamellata, at present a northern species in these islands, and not known in recent times south of Yorkshire, though since it occurs at Copford, as well as at Barnwell, it must certainly in Pleistocene times have spread at least down to the watershed of the Thames.

The single specimen of *Vertigo edentula*, in Mr. Dewick's collection, is remarkable for being the scarce varietal form (var. *columella*, v. Martens) which, originally found in Würtemburg, has since been noticed in Ireland.*

Balea perversa is represented by a young individual of only three whorls, and hence is put down with a "?"; but a careful comparison with recent examples under the microscope shows so close an agreement that no doubt exists in our minds on the subject.

---

* 'Jeffrey's Brit. Conch.,' i, p. 269.

The remaining addenda do not seem to call for any special notice, nor is it yet time to comment on certain conspicuous absentees.

Amongst the species which are still living in this country it may be remarked that the specimens of *Limnæa peregra* and *L. auricularia* from these gravels, are very difficult to separate sharply from each other; those attributable to the former species are nearly all very much inflated examples of the variety at one time called *L. ovata*, but forms seemingly intermediate between the two species are by far the commonest met with.

Limax lævis has only lately been recognized as an inhabitant of Britain, and its occurrence in the fossil state has also been overlooked, its shell resembling small forms of *L. agrestis.*

The following names, one of which appeared in Mr. Dewick's list, and the remainder in Mr. Bell's supplement thereto, have had to be withdrawn for the reasons stated :—

*Helix rufescens,** the York specimen proving to be *H. concinna.*

Pupa umbilicata, not to be found.

Clausilia biplicata, shown to be *C. pumila.*

Pisidium Henslowianum } now considered as vars. of *P.*
,, *pulchellum* } *fontinale.*

,, *nitidum,* the specimen so identified being a swollen form of *P. fontinale.*

---

* Of six specimens attributed to this species in the British Museum, three proved to be *H. concinna;* whilst the other three, although correctly determined, had manifestly come from the top soil.

ORDINARY MEETING.

FRIDAY, APRIL 6TH, 1888.

F. W. RUDLER, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association :—H. Kynaston ; J. E. Sharman.

The following Papers were then read :—'On the discovery of *Elephas primigenius* associated with flint implements, at Southall,' by Mr. J. ALLEN BROWN, F.G.S. ; and 'On the Influence of Geology on the Early Settlements and Roads,' by Mr. F. J. BENNETT, F.G.S.

There were exhibited :—

Flint implements and fragments of bones of mammoth and other animals, exhibited by J. ALLEN BROWN, F.G.S.

ON THE DISCOVERY OF ELEPHAS PRIMIGENIUS, ASSOCIATED WITH FLINT IMPLEMENTS, AT SOUTHALL.

BY JOHN ALLEN BROWN, F.G.S., F.R.G.S., &c.

Fossils of any kind are of such rare occurrence in the higher drift of the Thames Valley that their discovery should, if possible, be always noted and the remains described.

In this instance I have to record the occurrence of apparently the greater portion, if not the whole skeleton, of a mammoth associated with human relics under circumstances of more than ordinary interest.

In September last some extensive drainage works were being carried out at Southall, and deep trenches, about three feet wide, for the reception of pipes were made in the drift deposits, often penetrating the surface of the Eocene beds beneath them. Among other places in the district, these cuttings were exposed in the Windmill Lane, a road running from Greenford, through part of Hanwell, across the Great Western Railway to Woodlake, skirting Osterley Park, and thence towards the river.

Similar excavations were also made in Norwood Lane, which leads from Windmill Lane to Norwood Green, the junction of the two cuttings being near Windmill Bridge, over the Brentford Branch of the Great Western Railway.

The remains of the elephant were found in Norwood Lane, about 550 yards from the junction of the two roads, at the 88th-foot contour, and at a depth of 13 feet from the present surface. They occurred in a bed of sandy loam, which is here intercalated between coarse stratified sandy gravel. The gravel above the sandy loam is surmounted by a deposit of brick earth not exceeding a foot in thickness.

According to the account given by the labourers engaged in the work, the greater portion of the bones of the fore-part of the animal were either taken out of the "shore" or were seen on the sides of the cutting. I visited the spot a few days after the fossils were discovered, some of which had been thrown back into the excavation, but I obtained a large hand-bag full of them, some of which are now exhibited. Among them are broken pieces of the leg bones, a portion of the jaw, two of the molars, and some remains of the tusks ; a part of a third tooth was in my hands, but it was so much decayed that it crumbled into small pieces in transit. In fact, all these remains, in common with most of the fossils found in the higher river drift beds, were so softened by the action of water as to render their exhumation and removal a matter of great difficulty under any circumstances. When they were dried and regelatinized many of the fossils were in too fragmentary a state to admit of their precise determination with certainty, though it is clear that portions of the jaw and fore-leg bones are among them. They are not rolled by the action of the stream, and the joints and articulations are quite unabraded.

The molars are in much better condition, although imperfect. They appear to me to have belonged to a rather young animal, as the crown of the best preserved tooth is not so much worn down by use as would be the case in an older creature; the tusks are represented by mere fragments. It is most unfortunate that I was not present when the remains were discovered ; the greater part of the latter could then no doubt have been obtained, as the labourers described the tusks as being found extending in a curve from side to side of the cutting, and apparently attached to the skull, some portions of which appear to be among the remains in my possession. Some large bones were noticed on one side of the excavation, but as the only object of the workmen was to form the trench they were not dug out.

There seems to be no doubt, from what I saw and heard, that all the bones were in natural juxtaposition; and it is probable that the whole of the remains might have been obtained if means had been at hand for preserving them, and if the sides of the excavation, in which the greater part of the elephant was no doubt embedded, could have been carefully worked into. But although the occurrence of mammalian remains is rare in the river drift deposits above the 30th-foot contour, it is but of passing interest to a contractor's foreman. Some other bones (probably *Bos*) were found near the spot.

The number of flint implements brought to light at or near the spot where the elephant remains were found is remarkable, and the probable cause of their occurrence in such a position will be alluded to when the depth and other features of the river drift beds are considered later. Some of them were found in close proximity to the fossil bones, and one well-formed spear-head, which should be specially described, was met with, as I was informed by the workmen, in actual contact with them, while others were discovered very close to the remains. The most important of the implements should be noticed, as they are typical forms of the oldest of the specimens found in the higher terrace deposits. The same types are occasionally met with in beds of gravel at a lower level, and even in the bed of the present river; but they are generally much rolled, and are probably derived from the higher beds.

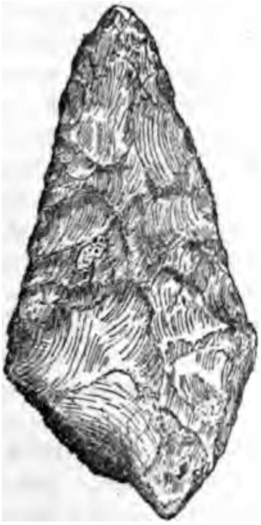


FIG. 1.

½ Natural Size. Large Palæolithic Implement from Southall.

In my collection from this spot is an unusually fine specimen of Palæolithic work. It is an implement of pointed type with straight sides, fully eight inches long (Fig. 1); it is very symmetrically and neatly worked; the butt is cut off or is broken off diagonally in a manner often noticeable in this type, of which I have other examples from the high terrace deposits of the Thames Valley, but whether this is due to accident or design it would be hazardous to say. This implement, although unusually large, is made from a water-worn nodule, a portion of the crust of which is seen near the butt, which is unworked; the other part of the surface is of a rich ochreous colour, and the chipping is almost unabraded. It was discovered in gravel, about 10 to 11 feet from the surface, in Norwood Lane, about 250 yards from the spot where the remains of the elephant were found, and about the same level (88ft).

It is a fact worthy of notice that large pointed weapons similar to this, of the same size and even larger, formed of quartzite and sandstone, were exhibited at the Indian and Colonial Exhibition in the collections made by Mr. Dunn and Mr. Bain from South Africa. They were described as "Elephant Axes or Choppers." Although these collections contained many stone implements of the Newer Stone period, which it is believed were used until recently by the most barbarous tribes of Bushmen and Hottentots, it is said there are no traditions among the existing tribes with regard to these older forms; and they may from their weathered appearance, in fact, be contemporaneous with the great glaciation which Southern Africa suffered, according to some authorities, comparatively recently, but, at any rate, since the Pliocene* period.

It should be mentioned here that, although the large implement was found near the same level as the bones—the intervening ground is higher, and the contour line rises between the two spots to nearly 100 feet—the river-drift deposits become thinner as the surface rises, until at the highest point the gravel and alluvium is diminished from, say, 15 or 16 feet to two or three feet. The sections, in fact, showed that the underlying London Clay rose to within two or three feet of the present surface at the higher point to the west, which intervened between the two sites. The implement and the mammoth remains were, therefore, deposited on, what would be at the time the creature lived, the gradual slope of the bottom of the stream rising in that direction. These facts will serve to account for the discovery of other implements in the vicinity.

Among the implements found in the excavations in Norwood Lane is one of ovoid form, nearly 5½ inches long (Fig. 4). It is worked all over and pointed at one extremity, but flat at the other, with well-worked cutting edges at the sides. The instrument, which is unabraded, was discovered about 50 or 60 yards away from the bones, and 14 feet from the surface. The same type has been found in the oldest cave deposits, and it was evidently, like the one next to be described, intended for use in the hand, without haft of any kind.

---

* See "Notes on a few Stone Implements found in South Africa," by W. Henry Penning, 'Journ. Anthrop. Inst.,' and Discussion by Prof. Rupert Jones and others.

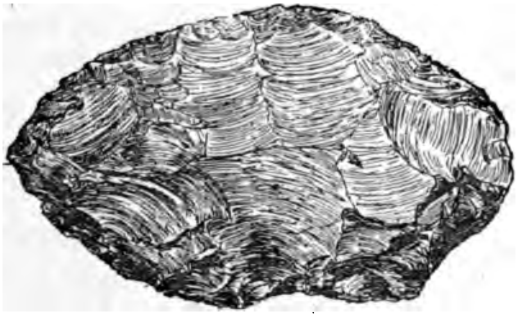


Fig. 4.

½ Nat. size. Palæolithic Implement from Southall.

A dagger-like implement (Fig. 3) was found also in Norwood Lane, about 200 yards from the fossil bones, and at about the same depth. It has a heavy, cumbrous butt, unworked, showing the rough surface of the nodule, but the sides are incurved towards the point. It is of deep ochreous colour and unabraded, except here and there but slightly, where the most prominent ridges of chipping occur.

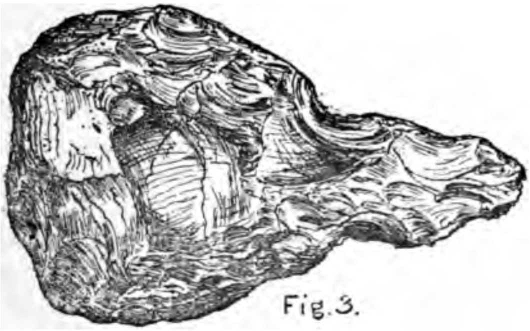


Fig. 3.

½ Nat. size. Dagger-like Palæolithic Implement from Southall.

A chopping implement or axe, formed from a rolled nodule, was also met with 40 or 50 yards away. It is rudely, but very effectively worked to a cutting edge in front, and reduced by chipping, apparently for insertion into a club-like handle.

Two points of implements, which were evidently broken off from specimens of the pointed St. Acheul type, were also found, the surfaces of fracture being as old as the other parts.

The spear-head discovered in contact with the bones (Fig. 2) is

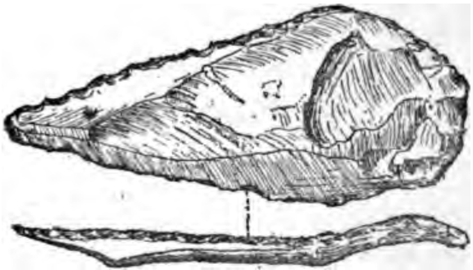


Fig. 2.

½ Nat. size. Palæolithic Spear Head from Southall.

a well-formed, perfect javelin or spear-point of greyish flint, nearly five inches in length. It is made from a flake symmetrically worked at the sides to a long point, and flattened at the butt for easy insertion into the shaft. The same mode of working is noticeable in many spear-heads from the Thames Valley in my collection, and formed a special feature in the numerous weapons of the like kind I obtained from the undisturbed Palæolithic warshop floor at Acton, many of which are as perfect as when they were left at that spot by their fabricators. These are described, with the method of working the nodule to produce this thinning out of the butt end, in my recently published book, 'Palæolithic Man in North-West Middlesex.' As I have previously pointed out, such javelin or spear-heads do not differ in any way, either in form or mode of production, from the points of obsidian and other siliceous minerals which are fixed into the shafts by gum and lashings, and used both as thrusting and missile weapons by the natives of the Admiralty Islands, New Caledonia, Australia, &c. It is not a little remarkable, too, that similarly-formed points of basalt, chert, &c., of Palæolithic age are found in Central India, specimens of which are now in my collection, obtained by Mr. A. C. Carlyle, late of the Archæological Survey of India. Man of the Palæolithic period, whether living in the Thames Valley or the banks of the ancient Narbudda, appears to have used the same simple forms.

Three smaller spear-head flakes, not so symmetrically chipped, but similarly-shaped, were also found in Norwood Lane, with a well-made shaft-smoother or spokeshave, the depression being very neatly chipped; also a smaller borer and flakes.

Although these objects were found at depths from the present surface of from 10 to 13 feet, they would appear from the varying thickness of the drift and upslope of the Eocene beds in this locality, to which I have alluded, to have been deposited about the same time.

At different spots, from about 400 to 600 yards distant, in a south-easterly direction, in Windmill Lane, there about 75 feet O.D., several other flint implements of similar old type were discovered, and many flakes, more or less worked with secondary chipping. Among the former is another rudely-worked, long dagger implement (Fig. 3), about 5½ inches in length, with the usual heavy, almost unworked, butt. It is chipped at the sides to a comparatively slender, sharp point, and shows but slight abrasion on the surface. A small implement, with a flat, neatly-worked cutting edge in front, and made otherwise by coarse flaking, was also found there, as well as a flattened, oval instrument like the last, worked all over, but much more abraded. It is nearly 5½ inches long, convex on one side, and incurved or concave near the point on the other.

Under what circumstances was the carcass of the mammoth deposited whose remains were in part exhumed, and how does it happen that its immediate neighbourhood should prove to be so rich in human relics?

The answer to this question is less difficult than generally happens, and the problem is more easy of solution from the evidence presented by the long-continuous sections afforded by the excavations than is generally the case where mammalian remains are found associated with relics of human work in Valley drift. Let us examine this evidence.

If a line be drawn from the County Asylum, in the Uxbridge Road, which is at about the 70th-foot contour, due south as far as Woodlake, Osterley Park, the present level will be found to be the same, or within three or four feet of the same, contour; but if it is made to the south-west, to the second bridge over the canal, near which the mammoth, &c., were found, the ground rises rapidly from the 70th to the 100th-foot contour line. The decline is towards the Brent Valley, which was probably in early times an old channel of the Pleistocene river, which has been still further eroded by the present small stream. Sections in the Thames Valley often show, as in this case, that the thickest beds of drift of the higher bench deposits are found in hollows or depressions of the London Clay beneath them, and that the gravels and sands are often laid down against the rising surface of the undulating Eocene bed. Such is the case in this instance. The old river drift beds commence at the Uxbridge Road with a thickness of 16 or 17 feet, but as the higher ground in Norwood Lane is approached they rapidly become thinner, until at the 96 feet O.D. they were found to be only two or three feet in thickness, as previously mentioned. In descending the gradual slope to the south in the direction of the Thames the drift thickens again, and the surface of the underlying London Clay again falls away beneath it. In fact, if the old river beds were entirely removed, we should find the surface of the London Clay rising from beneath what is now the 70th to the 100th-foot contour to the south-west from the Hanwell Asylum, and then falling again towards the present river on the south. To the north a long tongue of drift extends to near Greenford along the 100th-foot contour, with a slope to the east to less than 60 feet O.D.

If the level at which the fossils, &c., were found (about 13 feet from the surface), at 88 feet O.D., represents the extent of the erosion of the Valley which had taken place when they were deposited, it is highly probable, if not actually demonstrated, that the higher ground on the west formed the land surface at this period, over which, however, the waters had previously flowed, as indicated by the thin deposit of gravel found there, or which was subsequently covered by the action of a swollen stream or flood. At this slight increase of the level either occurrence may account for it. The rising ground to the west at this period would then form the banks of the ancient river which curved in a northerly direction, its old channel being indicated by the tongue-like extension of the river drift to the north, seen in the Drift Map, which is also bounded on the east by higher ground. This view is confirmed by the sections, as the bed of loamy sand containing the fossils thickened along this line, showing that calm water had flowed there; and two flakes were found in the excavations in this locality.

It is known, however, that the higher beds of drift are very unequal in thickness, according to the undulating surface of the Eocene bed to the west, and that coarse gravel is found at the same level as the sandy bed at no great distance from it. It is possible that the upslope of the London Clay may, therefore, have formed an island, with tranquil water on one side and a stronger current on the other.

The evidence afforded by the sections clearly indicates that either the banks of the larger river of the past must have existed near this spot or the rising ground of an island in the stream. The elephant either drifted into the shallow, tranquil water close to the bank or was driven into the clayey silt of the shore, in which its remains were found, by the Palæolithic hunters who have left us so many of their implements as evidence of their presence in this locality at the time.

As Lyell has so well observed: "The endless variety of the sections of the alluvium of the Valley of the Somme, the Thames, &c., may be ascribed to the frequent silting up of the main stream and its tributaries during the different stages of the excavation of the Valley, probably also during changes in the level of the land. As a rule when a river attacks and undermines one bank it throws down gravel and sand on the opposite side of its channel which is growing somewhere shallower, and is soon destined to be raised so high as to form an addition to the alluvial plain and to be only occasionally inundated. Sometimes an island is formed in mid-stream, the current flowing for awhile on both sides of it, and at length scooping out a deeper channel on one side so as to leave the other to be gradually filled up during freshets, and afterwards elevated by inundation mud or brick earth." These brief sentences convey what actually took place before and after the deposit of the remains of the mammoth and the associated human relics at Southall.

The occurrence of so many implements at about the same level there, is itself indicative of an old inhabited land surface in their immediate vicinity, especially as most of them show little effect of rolling with the stones of the gravel, and have not been carried far, if removed at all, by the stream.

The spear-head found in contact with the bones leads directly to the conclusion that it had actually been used, with others, for hunting the animal or cutting into its flesh. At any rate, it seems difficult to avoid the inference that there is a historical connection between the remains of the elephant and the implements found in such close proximity to them. The subsequent alteration in the currents, and probably in the channel of the stream, by which these interesting relics of the remote past were covered up, tells the same tale of old habitable land surfaces inundated, eroded, and destroyed, and new ones formed, which is noticeable all over the Thames Valley.

In the sections at Southall there are no more indications of rapid torrential currents than are generally seen in the deposits of high terrace gravel; clayey beds at the top, with alternating sand and gravel deposits, and bands of black matter, and whitened pebbles, with angular fragments coated with humus characterise them all. The disturbance of the beds and their frequent redeposit throughout the vast period, which seems necessary for the erosion of the Thames Valley to its present depth and width, is often clearly shown. The former presence of ice in considerable masses traversing the beds is seen in the large blocks of Sarsen, &c., found in the gravels, and in the unstratified aggregated masses of stones, &c., which occur in the upper beds, as well as the contortion of the deposits which is occasionally visible.

Floods and vast inundations probably occurred periodically, and on such a great scale as we may partially realise, when we contemplate the widespread effects of the same action which, under certain conditions, take place in the present day—such as the accumulation of ice which, assisted by a heavy snowfall, causes some of the great European rivers and their tributaries to inundate even now to the depth of 10 to 20 feet or more—great tracts of country; but the facts, as far as the Thames Valley goes, offer no evidence of a universal flood which has recently been suggested to account for the extinction of the mammoth. All the variations in the sections of the drift deposits observable in the Thames Valley are such as we may very well expect to find if we give time enough to a wider river flowing through a more level country during a period of increasing elevation of the land, subject in consequence to greater changes of channel and variations of currents; adding to these conditions colder winters than we now have, producing greater accumulations of ice and snow, and succeeded by warm springs and summers, thus bringing about rapid thaws and far greater floods and inundations than we have now, overflowing the unconserved, wild river of the past. Nor are these alternations of cold and heat altogether abnormal, for we can still point to the northern regions where they occur.

Bones and part of the tusks of mammoth were discovered in digging the foundation of the Southall Gas Works a few years since. They have also been found in high bench drift in Pall Mall, St. James's Square, Gray's Inn Lane, at Clapton, Kingsland, and towards the mouth of the river at Erith and Grays Thurrock. Colonel Lane-Fox's discovery of a single tooth at a high level at Acton is the latest find in that locality.

The lower ground (mid-terrace) of Kensington, Battersea, Hammersmith, Turnham Green, Brentford, and Kew, and very recently Twickenham, has, perhaps, furnished more specimens. They have also been taken from the old bed of the Thames at Milbank and London. I may also mention in this connection that bones, &c., of mammoth have been met with in the upper reaches of the Thames, as at Taplow, Hurley, Maidenhead, Wytham, Peasemarsh, and Oxford.

The mammoth, as appears by the evidence, existed in the Thames Valley when the river flowed a hundred feet above the present stream, and it lived on into the mid-terrace period, and probably later, as its remains have been met with at a lower level. It may even have survived in North-Eastern Europe and Northern Asia to a still more recent date. A vast period, represented by the time involved in the erosion of the Thames Valley, has elapsed since it first frequented the banks of the old river with other extinct and many existing forms, including man. There is no evidence whatever in the Thames Valley of any cataclysm or universal convulsion to which its extinction is to be ascribed, or of its sudden extinction at all. Probably it never was so abundant in Southern Britain as it was in the northern parts of Eastern Siberia and the adjacent islands; and it appears to have died out here from the same causes, climatal and other changes, floral and faunal alterations, including the destructive hand of man, which have operated in causing the gradual extinction of other Pleistocene animals, some of which survived, like the great Irish elk, into the verge of the historic period; while some, such as the reindeer, glutton, marmot, &c.,

forsook their old haunts, and slowly retreated into more congenial regions to the north; and others, like the sturdy, irrepressible hippopotamus, that old inhabitant of this country which even "Time" before the Flood, as well as the supposed "Flood" itself, seems to have spared, retired to their present abode on the bank of the Nile and other parts of Africa.

INFLUENCE OF GEOLOGY ON THE EARLY SETTLEMENTS AND ROADS.

BY F. J. BENNETT, F.G.S.

It is generally admitted that we owe much to our mothers in the formation of our characters, but at the same time we also owe no small share to the physical environments of the particular spot in which we were born, and where we passed some years of our lives. The mountaineer differs from the lowlander, and the dwellers on the coast from those inland. Those who have to struggle with adverse physical conditions, and who live toilsome lives, differ much in character from those to whom Nature has been bountiful, and to whom toil is unknown. The awful phenomena of volcanic regions cause the inhabitants of those districts to be superstitious in the highest degree, though in most of the isolated districts in our country we also find much superstition. All this, of course, is well known, and has been most ably treated by Buckle in his 'History of Civilization.'

My object is to show that geology has also played a very important part in determining the sites of some of the early settlements, and the direction and position and general condition of roads; it may be added, too, that the courses of rivers have been much influenced by geology.*

My remarks will be confined to this country, and I do not intend to go further back than to Neolithic times, our knowledge of the much remoter Palæolithic period being far too scanty to afford any reliable data.

The early settlers of the remote Neolithic period must have been very much restricted in their choice of the sites for their settlements. They were, no doubt, at first a pastoral people, and later on tillers of the ground; their only tools or weapons were of stone or bone, and, therefore, ill-adapted to fell trees, or to clear and cultivate the soil. These early settlers then must have been confined to those formations and situations unfavourable to the growth of trees, and where open expanses of turf for pasture were to be found, and where suitable stones for their tools could be procured. All these conditions are to be found on the chalk downs, though not confined to them.* Of course, even with their primitive tools and by the aid of fire, clear spaces could have been made in the forests, but I imagine the naturally cleared spaces would have had the preference, especially with the early settlers. When it came later on to a struggle for existence, the better armed would seize the river-valleys, and the ruder people would be confined to the downs.

---

* The connection of geology with scenery has been well shown by Sir A. Ramsay in his 'Physical Geology and Geography of England,' and by Dr. Geikie in his 'Scenery of Scotland.'

On these downs we find abundant traces of the early settlements in the shape of camps and tumuli, though the former may have been only used as places of refuge. The surface of the ground is strewn with flints, and here and there we find the chipped tools of the early settlers.

That the turf of these downs dates back to very early times has been pointed out by me in a paper read before the Newbury Field Club†, in which reference was made to the figures cut in the chalk downs. Whatever the age of these chalk turf intaglios may be, it is quite evident that these downs were in turf long before they were cut. The White Horse at Uffington, the "Wilmington Giant," 240 feet high (near Lewes), bearing a staff in his hand, and the "Cerne Giant," 180 feet high, with a club measuring 121 feet, are well known. The cross of Prince's Risboro', 100 × 50 feet, and that at Bledlow close by, are not perhaps so well known.

Hence we may infer that these downs are much in the same state now as they have been for a very long period of time. Then we have the names of Highclere, Burghclere, and Kingsclere on the chalk downs near Newbury. What the age of these names may be is not certain, but the termination "clere" would seem to denote a clearing.

We find abundant evidence that these spaces had been cultivated, as they are marked all over with slight ditches and "baulks," forming square inclosures.

Mr. Baigent pointed out at the excursion of the Hampshire Field Club to Burghclere in July, 1885, that there was documentary evidence showing that these hills had been cultivated from very early times down to the time of Edward III., and that it was due to the ravages of the Black Death in 1347 that they went out of cultivation.

---

* The Cotswold Plateau consists of open downs, and so also the eastern moorland of Yorkshire. Here we find extensive prehistoric remains.

† See 'Trans. Newbury Field Club,' Vol. iii, p. 255.

Again, Mr. Topley, in his most interesting paper on the 'Parish Boundaries in the South-East of England,'* states that the face of the Chalk escarpment around the Weald is divided among 125 parishes, 119 of which belong to parishes lying beneath the escarpment, and only six to the Chalk above. He considers that the latter were the earliest settlements. On the plateau where there is no drift, he says, all was turf, and there are found abundant Celtic remains. He says, further on, "Taking the case of that part of Sussex represented in Plates II. and III., we can have little doubt that the whole of the Chalk area as far west as the River Arun was quite open land."

These are the arguments, not very strong ones perhaps, for the proof of the early settlements on the open down and moorland country. We may add that we find the modern settler prefers the prairie to the forest; in the open prairie he can begin to plough and get in his wheat at once with no clearing to do. Leaving the true chalk down country, we come to Norfolk and Suffolk, at the meeting of these counties near Brandon. Here we find an open chalk country, and were it not that the Chalk is covered with a variable drift of clay and sand, in which the latter predominates in that a coating, mostly very thin, but sometimes thick, covers everything, we might have had a down country. As it is, owing to the sand covering, it is a wild, mostly barren, heath. Now and then we find large woods, mostly of fir, but these are of recent introduction, and probably the original state of the country was that of heath and scrub. Flint knapping, as Canon Greenwell† has pointed out in his able paper on 'The Opening of Grimes' Graves,' has been carried on there from Neolithic times down to the present day. Brandon seems to have been the Birmingham of that period, and the centre, perhaps, whence the flint knappers spread. It was the occurrence of the Chalk-with-Flints, and the particular flint bed best suited for flint implements that determined the site of the Brandon settlement. The observations of Canon Greenwell, supplemented by those of Mr. Skertchly, show that the flint knappers of the present day are the direct descendants of the Neolithic workers; they mine for the same bed of flints in a manner only slightly different from that their far-off ancestors adopted; they also chip the flints in the same way, and the tools they now use are copies of the old stone and bone ones. The present workings are on the Ling Heath, on the Suffolk side of the river; the old workings at Grimes' Graves are on the Norfolk side, and the pits are some 250 in number. The old workers reached the flint bed by a direct vertical shaft from twenty to sixty-five feet in diameter, and then worked out the flint in galleries, which seem to have connected all the shafts. The flint seems to have been removed from the bottom of the shaft by ropes of hide, or by ladders made out of the trunks of trees. The modern way is to reach the Chalk by a series of short slanting shafts, with level landings at intervals, the workman carrying the flint on his head, placing it on the landing, then climbing up the incline, and so on till he reaches the surface. The old workers removed the chalk only above the flint bed; the modern ones above and below the flint. The Neolithic worker seems to have used a rude saucer-shaped oil lamp, made out of chalk; the present ones use wax candles. The "Floor Stone" is the name of the flint bed from which the implements were made. That bed at Grimes' Graves is about seven inches in thickness; about twice that of the bed in the modern workings, and of a much finer grain. The ground for some distance round Brandon is strewn with flint chips, and worked flints are also very numerous; and not only may surface Neolithic specimens be found, but the river-gravels and the brick-earths at and near Brandon yield Palæolithic implements, thus affording evidence, no doubt, of a settlement of much greater antiquity in this area.

---

* 'Journal of the Anthropological Institute,' Vol. iii.

† "The Opening of Grimes' Graves," 'Journal of the Ethnological Society of London,' January, 1871.

After settlements came towns and villages, and the part that geology has played in determining their sites is a subject of much interest. As before remarked, the early settlements were on the open country, and if we take the case of the North and South Downs we find few, if any, traces of the early settlers in the Weald, the reason being that this part of the country was one vast forest (Anderida), and for the most part inaccessible to the people of the Stone Age. The most thickly-wooded parts of the Weald, Mr. Topley points out,* were those occupied by the clay, now the arable land. What is now left of this forest is that on the less valuable light land, where the trees would not be so vigorous as on the clay. Later on, we find at the foot of the escarpment numerous villages, most of them resting on the Upper Greensand, and we find the parish extending from the Gault up the scarp ; so that each village had its due share of pasture, arable, and woodland. This very equitable arrangement would of itself denote that the country has been settled a long time, and that the inhabitants felt the necessity of living peaceably together. These villages would obtain their water supply from the springs at the junction of the Chalk and the Upper Greensand.

---

* *Op. cit.*

Generally throughout England in the wide areas of the Clay formations no towns or villages were to be found where the clay was alone to be met with, but where beds of sand and gravel capped the clay their occurrence decided the sites of the communities as being places where water could be found; so that the mere presence of the old towns and villages would show the spots where the water-bearing strata existed. This was notably the case in the London Clay of London, on which the extensive clay tracts were bare of houses before the existence of the great water companies.

Mr. Topley, in his paper before referred to, says that "the eastern part of Northumberland is much covered with Drift deposits, chiefly Boulder Clay, there rise up in many places isolated areas of sandstone belonging to the Coal Measures and Millstone Grit. On these rocky patches most of the ancient villages and the more important hamlets are built. Here the soil is dry, and springs occur at the edge of the clay. The sites of these old settlements were determined by the surface soil."

The question will at once arise how, if these early settlements were, in the case we have been discussing, confined to the now dry and springless chalk downs, did they obtain their water-supply? In some of these broad upland valleys we find the Bournes (sometimes called Lavants, Nailbournes, Winterbournes, and Gypsies) which are intermittent streams and only burst forth every three or four years; but it has been remarked that as it is very probable that the rainfall in former times was greater than it is now, so these Bournes may then have been permanent streams. We have, however, still to account for the water-supply for the cattle on the downs and for that of the camps, which has been a matter of much conjecture. I think the water-supply in both these cases may have been from dew-ponds, which are well known to be of ancient origin. These dew-ponds were, no doubt, found naturally at first in the hollows in the ground, the water being kept up by such beds as the Clay-with-Flints that covers extensive tracts on the Chalk. Afterwards it would be found that the ditches of these camps also acted as dew-ponds, the tramping along them during their excavation puddling the chalk sufficiently, and so making it watertight; or clay might have been employed for that purpose. These wet ditches would also add to the strength of these camps.

A few words may here be said about dew-ponds. These ponds are said to attract the mists, which are denser and more frequent at these high elevations than in the low grounds; and the rain and snowfall is also greater, both of which causes would help in keeping them full. The rainfall is found to increase three per cent. for every hundred feet, and it must be borne in mind that the evaporation on the high grounds is much less that on the low lands. Mr. Baldwin Latham states that he does not know a single dew-pond that has not a certain amount of drainage into it. He also noticed the case of a lake in Wales at an elevation of 2,000 feet when the water seemed in direct communication with the clouds while the sky all around was quite clear. These ponds are still being made on the high spurs of the chalk downs. They should be so situated that the slope of the spur is toward them, thus taking some of the drainage from it. They vary from thirty to forty-five feet in diameter, the bottoms are puddled and so made watertight, and they are never known to fail when properly constructed. Many of the modern ponds are cemented at the bottom, and if properly done will last a long time. One thousand sheep have been daily watered from some of them in seasons of drought.

We now come to the next division of our subject, viz., the connection of geology with roads.

As a cyclist from the days of the "boneshaker," I have naturally paid much attention to roads, and as a student of geology have long seen how much that science has to do with them. Some ten years ago a friend of mine, no geologist, but a shrewd man and an experienced rider, had taken a bicycle tour from Norfolk into Derbyshire and back; and on getting from him the line of his route, and without telling him my reason for so doing, I took my geological map (Ramsay's Map of England) and plotted out the roads he had followed from it, putting in and colouring the geology of all the different formations he had passed over, and then drawing up in a tabular form an estimate of what was the gradient, road material, general condition, and average riding state of the roads over each of the formations he had ridden over, and then sent it to him asking him to say how far it accorded with his experience. He wrote back to say that he was completely astonished that a person who had not ridden these roads (as in my case) should be able, from the geology alone, to form so accurate a conception as to their general condition, &c. Again, when walking out soon after this with a professional geologist, a colleague of mine, in a country well known to him—he having mapped it—but quite fresh to me, I said "Now I will try and tell you what the geology is from the surface of the road alone," and I was able to say correctly in each instance that it was either bare chalk, sand, or clay, very much even to his surprise, since, not being a cyclist as well as a geologist, he had not paid the same close attention to the matter that I had.

Again, by taking a map on a scale of at least one inch to a mile and noting the number of roads passing through any district, we may get some idea of the nature of the strata; for if we find that there are few roads we may infer that road-metal is scarce and that the strata comprise either loose soils with no hard beds, or clays without any stone bands. The fertility or sterility of a district, too, is often shown by the size of the farms and the fields. Where the fields are small, and therefore numerous, we may gather that the land is fertile and therefore valuable, but where they are few and large we may, as a rule, conclude that the land is either sterile or less fertile. We often find a greater number of footpaths when the land is comparatively valueless and unproductive.

There can be little doubt that in pre-Roman times, and before the art of road-making, the means of communication were confined mainly to those parts where the strata supplied road-metal and the roads were not liable to be flooded, and where, as in the case of the chalk downs, there were no forests. For a long time in Britain there must have been no real roads, nothing but mere trackways, and many of these only available in the dry seasons.

Cæsar's advent, however, must have found the Britons in a state of some considerable civilization, as we find they used in their battles a vast number of chariots. The use of wheeled vehicles always denotes considerable constructive powers and therefore a great advance in manual skill. Unless these chariots were confined to the open down country, where no roads would be needed, they would have been useless without some kind of road, and yet it appears from Cæsar that the charioteers (essedarii) formed a regular part of their army and that they usually fought from them, so that it may be that they had something in the shape of roads that would at least have been available in the summer time, warfare being impracticable in the winter. No doubt these chariots were of a very light construction, and perhaps the bodies were made of wicker covered with skins, like coracles. These chariots may have been confined to the tribes of the eastern and southern coasts, who, according to Cæsar, were more civilized than the rest, and on these coasts we find the down country.*

But whether the Britons made anything at all in the shape of roads it is quite certain that the introduction of the Roman highways must have caused as complete a revolution in the traffic and life of the period as did the coach roads much later on, or the railways of the present day. Parts of the kingdom inaccessible before, and cut off from all intercourse, were rendered accessible.

The first Roman roads constructed were, no doubt, from the landing places of the invading fleets to the great British settlements near the coast-line, and thence to the principal military stations.

We find many early British strongholds and all the pre-historic ones on the commanding elevations on the chalk and other downs. The old camps follow closely the contour lines of these hills. These and other forts would be at once reduced by the Romans and their roads would frequently be directly to them.

So scientifically were these Roman roads constructed that some around Rome remain in use without being repaired down to the present day. The number of them in Britain is most astonishing, though there is little left of them as originally constructed, and that remnant is confined to the hard rock country, where, stone being abundant, there would be no great temptation to remove the road material. But where these roads passed through the softer beds, the hard stone of which they were made was to a large extent removed in later times and used for building purposes.

It may now be interesting to show the mode of construction of these roads. The Romans are said to have adopted their first ideas upon this subject from the Carthaginians, and it is extremely probable that the latter people may, from their commercial activity and from the sandy nature of their soil, have been compelled to turn their attention to the best means of conveying their merchandise to the different parts of their territory. It must not be imagined, however, that the Roman employed from the first the elaborate system about to be described.

---

* The Pilgrim's Way, passing, as it does, many ancient earth-works, is presumably pre-Roman (*vide supra*, p. 155, and the references there given), as are also some of the tracks through what was once the forest of Anderida. (See 'Oldbury and its surroundings,' by George Payne, Maidstone, 1888).—[Ed].

Vitruvius enters into no details as to road-making, but he gives most minute directions for pavements, and the fragments of ancient pavements still existing and answering to his description correspond so exactly with the remains of the military roads that we cannot doubt that the processes in each case were identical, and thus Vitruvius, combined with the poem of Statius on the Via Domitiana, will supply all the technical terms.

In the first place two shallow trenches (*sulci*) were dug parallel to each other, marking the breadth of the road. This in the great roads, such as the Via Appia, &c., varied from 13 to 15 feet; the Via Tusculana is 11 feet, and less important roads, such as the one which leads to the Temple of Jupiter Latialis, on the summit of the Alban Mount, which is singularly perfect to this day, seem to have been exactly eight feet.* The loose earth between the trenches was removed till a solid foundation (*gremium*) was reached; but, if the ground was soft or swampy, piles were driven. Above the *gremium* were four distinct strata, the lowest, or *statumen*, of stones not smaller than the hand could grasp; above this the *rudus*, a mass of broken stones cemented with lime, rammed down hard, and nine inches thick; above this the *nucleus*, broken bricks and pottery, in small pieces, and cemented with lime six inches thick. Uppermost was the *pavimentum*, large polygonal blocks of the hardest stone (*silex*), and, near Rome, of basaltic lava, irregular in form, but fitted with the greatest nicety and making one solid mass. The centre was a little elevated to permit the rain to run off. When the road passed over solid rock the *statumen* and the *rudus* were dispensed with, and the *nucleus* spread at once over the rock. Footpaths strewed with gravel were also made.*

---

* It is most interesting to find that this is the width of the *Via Julia* between Soudley and Blackpool Bridge, in the Forest of Dean, part of the military road from Gloucester (*Glevum*) to Caerleon (*Isca Silurum*) made by Julius Frontinus in the reign of Vespasian, as shown by the skilful researches of Mr. John Bellows. It is thus described by the late Sir W. V. Guise: "Where it remains perfect it consists of roughly-squared blocks of conglomerate or of Millstone Grit, of ten inches to a foot cube each, with a well-set line of marginal stones, about fifteen inches long by five inches wide and ten inches deep. These bordering stones, which are of hard Forest rock, are again supported by a buttress-line of large blocks outside, and set a few inches below the level, serving probably also as a gutter to prevent washing away of the substratum. The average width of the roadway is eight Roman feet; that is, rather less than eight English feet. The strength of the work is such that, after the lapse of all these centuries, but for the use that has been made of it as a quarry for roads, fences, and buildings, it would have been in good order still."—'Proc. Cotteswold Nat. Field Club,' Vol. vi (1872-6), pp. 189, 287.—[Ed.]

It can easily be imagined that roads so made must have rendered all the parts of our country served by them easily accessible; and as the early settlements were on the firm and hard strata, the Roman roads would be constructed to them, and thence also road metal could be conveyed to those portions of the roads passing over the soft strata, where before there had been no roads. Coal must have been conveyed along these roads for considerable distances, for we find the Romans using this fuel in their hypocausts for warming their houses ; but whether they discovered this mineral or learnt its use from the natives is uncertain. These roads may also have contributed to the opening up of our iron and lead mines, of which metals we know the Romans raised large quantities.

Such roads as the Romans made would be far less affected by the varying subsoil than the very thin-skinned roads now in use.

It was no doubt part of the policy of the Romans in the erection of their buildings and in the construction of their roads to make them so massive and permanent. The nations brought under their sway would thus be compelled to conclude that they intended their rule to be equally strong and settled, and the moral effect of all this must have been very great.

After the departure of the Romans, we find from internal evidence that our roads right up to the Middle Ages remained in good condition, for we learn that very rapid journeys were then made. But after that time a very rapid deterioration set in, till from the seventeenth to the middle of the eighteenth century the roads became so bad that travelling was only resorted to in cases of dire necessity. Down to the year 1736 the roads round London even were so bad that in wet weather a carriage took two hours to crawl from St. James's Palace to Kensington. Those portions of the country where the softer beds prevailed, and which were distant from water communication, must again have been quite isolated.

---

* I am indebted to Smith's 'Dictionary of Antiquities' for the above account.

But in the Middle Ages merchandise seems to have been conveyed mostly on pack-horses and by packmen, and we often find, in parts of the country, roads still called "the packway." It was this kind of traffic that, by strings of horses, caused most of the "hollow ways" we still find in many parts of the country, though some no doubt are due to natural causes. Some of these hollow ways are to be seen side by side with the coach roads, and are very deep and narrow. In sandy districts deep-cut lanes are a most marked feature, and are due mainly, of course, to the soft nature of the soil into which the pack-horse traffic would cut deeply, and a channel being thus made the rain would soon hollow it out. These lanes are so narrow that the projecting packs would easily touch the sides, thus aiding the excavation.

So bad were the roads toward the end of the last century that, in spite of the canals, commerce suffered so much that Parliament had to take up the matter; and then we find Macadam and Telford coming to the rescue, and on the advent of the railways our roads had reached a great pitch of perfection.

Telford seems to have followed the Roman construction much more closely than Macadam, and laid a firm pavement first and then the broken stone bed on the top, whereas Macadam considered the paved bottom as useless, and constructed his roads wholly of broken stone. The majority of roads as at present constructed are on Macadam's plan. All the London roads seem to be made this way, and when steam rollers are used they quickly consolidate; but for some years our roads have been deteriorating most seriously, owing to the neglect of the teachings of Telford and Macadam as to their maintenance.

Where a very thick coating of hard stone is used, such as we find in London, the geology of the district does not affect them very much so long as that coat is kept in proper repair. When, however, we have a thin bed of stone, such as is the case in the country roads (and, as the rolling-in is, with most short-sighted policy, left to the traffic, this bed must be thin), we find that the roads will vary with the subsoil, even if one description of metal be used. For instance, if we take the case of a road passing over a clay and sand subsoil and metalled with one kind of metal, we shall find that during wet weather the clay subsoil portion will be much softer than the sand subsoil portion, and that in dry weather the clay part will keep firm much longer than the sand part.

Not only does geology affect the general condition of the surface of the road, but it also affects the gradients. These, of course, may have been equalized where the roads have been carefully engineered; but the majority of roads have not been so treated. Clay, sand, limestone, and such hard rocks as granite (and these four divisions will include all roads) have each their own angle of rest, and thus have each their own gradient; and as each of them in turn come to the surface this change in the formation will effect a change of feature in the road.

Springs will arise where clay is capped by sand, and, again, if a harder and more compact bed occur among those that are more porous and more fissured.

We will now take some of the formations that are widely distributed, and see how they affect the roads.

Taking the case of roads passing over such formations as the Oolite, we find that these beds make some of the worst roads we have, especially if they are metalled with the same rock. These roads are slippery and muddy in wet weather, and dry into ruts under the action of the sun, wind, and frost; whilst in very dry weather they are extremely dusty. The gradients are usually long and gradual, though very steep for a short distance at the scarp.

The gradients of roads on the Chalk formation—I refer to those portions that are free from drift—are much the same as those of the Oolite. When the Chalk is well metalled with flints picked off the fields we have very good roads. The flint being siliceous it much modifies the effect of the limestone, and prevents the roads becoming slippery. These roads passing over an open country soon become dry after wet, and keep firm a considerable time in dry weather. If the coat of metal be thin, the chalk will come to the surface during rain, and especially in frost, when what are termed "mustard pots" are formed. These thin roads will become rutty on drying. Some of the best of the Chalk roads are those along the dry Chalk Valleys, the bottoms of which are filled up with an accumulation of flints, most of which have worked their way down the flanks of the hills, thus making a good, natural foundation for the roads.

Mountain Limestone roads have very long and very steep gradients; and, though far better than the Oolite roads, they become muddy and greasy in wet weather, and, unless well made, rutty and dusty in dry weather, the metal used being commonly the broken Mountain Limestone.

In the London Clay district we often get very steep, though short rises, especially if the hills be capped with gravel. Here, again, much depends on the way the road is metalled: if indifferently done, the roads will be bad; but if well done, the roads will be fairly good, and occasionally very good. Near London these roads are metalled with some hard rock.

The Boulder Clay roads of the Eastern Counties, in the area of the thick Chalky Boulder Clay, must be well made. They then form good roads; but in those parts where the Boulder Clay is thin and patchy the roads are bad, though, of course, much might be done to improve them. As much of the Chalk in this part is covered with Boulder Clay, we find that as a rule the gradients resemble those of the Chalk, and when the sand and chalk beneath the clay come to the surface, the surface of the road is affected by these beds. The metal used is the stone picked off the fields, unless gravel can be obtained.

The roads in the area of the Bagshot Beds present long and easy gradients, with long stretches of almost level road on the top of the Bagshot table-lands. The subsoil being mostly dry, and a gravel drift being of almost universal occurrence, road metal is plentiful, and these roads soon dry after wet and are never greasy in frost, being of a siliceous nature. They do not stand a very long drought, unless, as in some parts of Berkshire and Hampshire, the beds contain much clay, and the gravel also has a clay matrix and binds well.

The best roads are found in the districts of the Hartshill quartzite, the Clee Hill stone, and the Whinstone.

Many towns are now using the Clee Hill stone, and find that the increased cost of this stone is more than made up for by the much decreased cost of scavenging. In one case where a limestone was used the proportion of mud per mile to that where the Clee Hill stone was used was 500 tons to 60.

We may, in conclusion, glance at the way that geology affects railroads, and the same remarks that apply to roads will apply to them, though in a modified degree, owing to the very thick ballasting used. Those lines passing through a clay country, or through formations throwing out much water, require far more care and attention than those passing through dry and rocky districts. Both cuttings and embankments—which are only the cuttings rearranged—are constantly slipping in clayey formations during wet weather, both in summer and winter.

ORDINARY MEETING.

Friday, May 4th, 1888.

F. W. **Rudler**, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following were elected Members of the Association:—W. E. Darwin, B.A., F.G.S.; E. Evans; A. S. Foord, F.G.S.; Miss M. I. Gardiner; F. May; and R. L. Mond.

The following papers were then read:—'On Palæozoic Arcidæ,' by Mr. J. Logan Lobley, F.G.S., and 'On Pterodactyls,' by Mr. E. T. Newton, F.G.S.

On Palæozoic Arcidæ.

By J. Logan Lobley, F.G.S.

So great is the number of fossil Lamellibranchs that hitherto there has been no such general and complete examination of British species as that to which the Brachiopods of British rocks were subjected by Dr. Davidson. The following contribution to a general review of British Fossil Lamellibranchiata may therefore not be altogether without interest for this Association.

Palæozoic forms of Arcidæ possess, however, more than a mere systematic value, since they have a general scientific interest that will be recognized by all our Members. One of the two earliest families of the Lamellibranchiata known, if not quite the earliest, the Arcidæ, flourish at the present time in all the seas of the globe, giving thereby a conspicuous proof of the marvellous continuity of bio-morphic types, or general organic form and structure, from early geological times to the present day. But great as is the generally interesting character of this wonderful fact in itself, its significance or indirect teaching is exceedingly great also, for it clearly indicates that other commandingly important fact, the continuity of general inorganic conditions which must have existed to allow of the uninterrupted succession of generally similar organisms, all requiring, therefore, a generally similar environment for their existence and welfare, as well as for the development of the type.

As silent, yet eloquent teachers of these great facts, Palæozoic Arcidæ are surpassed by only one other zoological family, the Lingulidæ, fossil representatives of which occur in still earlier rocks than those in which the remains of the earliest known Arcidæ have been found ; whilst this family of Brachiopoda, like the Arcidæ, is still existing. Even Lingulas, however, are perhaps less cogent in their evidence to the untravelled English naturalist, since we must go to distant seas to find a living Lingula, while highly developed and, so to speak, robust members of the family Arcidæ live in our British seas, and their shells may be picked up by our children on the sands of our English coast. To a London geologist, familiar with the large *Pectunculus Plumsteadiensis*, with which portions of the Woolwich Beds are crowded, with the small *P. decussatus*, abounding in one of the zones of the London Clay, and with the beautiful *P. glycimeris*, perhaps the commonest fossil of the Red Crag of East Anglia, Palæozoic species of the same family to which these familiar Tertiary shells belong, must have a special interest and significance.

That members of this family are found in the oldest rocks yielding lamellibranch fossils, is otherwise a noteworthy fact, since they are much higher in the scale of zoomorphic development than many other families of the Class, that might, therefore, be expected to occur in these rocks. But this instance of higher forms first appearing is by no means unique, for have we not the largest and most highly ornamented trilobites in the Menevian rocks, with smaller and simpler genera in rocks much newer, and graptolites, both large and complex, in abundance in the Llandeilo, with much more apparently primitive and smaller forms in the Ludlow rocks ?

Such facts, *primâ facie* in dissonance with the evolution hypothesis, may be accounted for, or rather, as it were, excused on the ground of the imperfection of the geological record, and confident predictions may be indulged in that a more extensive and complete examination of Cambrian or Pre-Cambrian rocks will reveal earlier and simpler forms in older strata, but, nevertheless, the anomaly is worthy of thoughtful consideration and ought not to be hastily set aside. It is not, however, the object of this paper to discuss such a question as this, but rather to give the results of discovery and examination.

The great bivalved class of Mollusca, named *Lamellibranchiata*, by De Blainville, from the lamellar or plate-like character of the branchiæ or gills of the living mollusk, and formerly called *Conchifera* by Lamarck, has recently been renamed *Pelecypoda*, or *axe-footed*, in order that this Class may have a designation in uniformity with those of the other great divisions of the Mollusca. This name, *Pelecypoda*, has been used by Prof. Tryon, the author of the great American work, the 'Manual of Conchology,' now in course of publication, and subsequently by Dr. Paul Fischer, in the splendid 'Manual de Conchyliologie et de Paléontologie Conchyliologique,' published only last year, and it is, moreover, adopted by our distinguished English palæontologist, Mr. Etheridge, in the new edition of Prof. Phillips's 'Manual of Geology.' I am, however, sufficiently conservative to adhere to good old familiar names, at least for some little time after the first publication of new designations, and although Pelecypoda is an old name revived, it has not been used for so long a time that it has the effect of a new word. It is based, too, on a less important organ than the name Lamellibranchiata, and an organ, moreover, that is not common to all Mollusca, since the so-called *podi* of Brachiopoda are not feet or organs of locomotion at all. I may add that although a longer word, Lamellibranchiata, is more euphonious than Pelecypoda, while a little variety is more pleasing and, perhaps, too, more mnemonical than a dull uniformity in classificatory nomenclature. I will, therefore, in this paper speak of Arcidæ as lamellibranchs.

The Class Lamellibranchiata—to adopt a good classification especially useful to palæontologists, though one not favoured by Tryon or Fischer—has been divided first into *Monomyaria* and *Dimyaria*, or those having only one adductor muscle, as the oyster and the pecten or scallop, and those having two, as the cockle and the mussel.

The order Dimyaria, in which is the family Arcidæ, is divisible into the *Siphonida* and the *Asiphonida*, some genera being furnished with siphon-like organs for the intaking of food-bearing and oxygen-bearing water, and its subsequent ejection, and other genera being devoid of such organs.

Then, again, some genera possess siphons which can be protruded outside the shell, and withdrawn again at will; and, since the retractile siphon is indrawn into a cavity in the body of the mollusk, the pallium, or mantle, is deeply indented by a bay or sinus, and this is clearly indicated by the "pallial impression" or marking on the interior surfaces of the shell, and so the mere shell alone suffices to establish the possession or non-possession of a retractile siphon by its former occupant.

Thus two other divisions are constituted the *Integro-pallialia* and the *Sinu-pallialia*—or those having the pallial impression simple or unindented, and those in which this line on the inner side of the shell is indented by a sinus, and it will be obvious that as this division is founded on an enduring marking on the enduring part of the lamellibranch, it is of very great classificatory value to the palæontologist.

The fossils of the Palæozoic rocks, especially those from Lower Silurian and Cambrian strata, are sometimes so imperfect and deficient in distinct characters that an attempt to arrange them with zoological correctness is necessarily attended with difficulty, and the results arrived at are best considered rather as approximations to correctness than as final determinations.

For our knowledge of fossil Arcidæ we are much indebted to American palæontologists, and the names of Vanuxem, Emmons, Conrad, Billings, and Hall must remain with those of Sowerby, Phillips, McCoy, and Salter associated with this, perhaps the oldest, family of the Lamellibranchiata, and the remarkable discoveries of our associate, Dr. Hicks, in the Tremadoc rocks of Ramsey Island, South Wales, in 1872, while extending the known range of Arcidæ, and, indeed, of the Class Lamellibranchiata, gave to science a new and well-marked genus that must be placed in this family.

In the year 1873, at the Bradford Meeting of the British Association, I read a paper giving the stratigraphical distribution of the British Palæozoic species of Arcidæ then known. Since that time but few additions have been made to the list, and consequently the statement of their distribution now will not differ much from that published in the British Association Report. Neither have I seen reason to alter the determinations of the generic affinities of the species on which the census of the distribution was founded.

The possession of the retractile siphon then appeared to me to be so important a zoological and physiological character that I considered that Integro-pallial and Sinu-pallial genera ought not to be included in the same family, and that Arcidæ should be restricted to those genera agreeing with the type genus Arca, on which the family is founded, in being integro-pallial, and accordingly it was proposed in the paper above-mentioned to remove the genera Leda, Yoldia, and Solemya, as sinu-pallial genera from Arcidæ altogether, and to establish a new and distinct family founded upon the genus Leda, the *Ledidæ*, and this view was not opposed by the Section.

In the large work by Professor Tryon the lamellibranchs are not yet reached, but that author has completed a smaller work in three volumes, entitled, 'Structural and Systematic Conchology,' based upon the wonderful book of Dr. Samuel Woodward, the well-known and justly-esteemed 'Manual of the Mollusca,' a book in which the maximum of sound knowledge and scientific information is compressed into the minimum of space, and I have great satisfaction in finding that my proposal of fifteen years ago for the restriction of Arcidæ has been adopted in the classification given in this recent general work on the Mollusca, as well as in that of the still more recent work of Dr. Paul Fischer.

With the elimination of the sinu-pallial genera the definition of the family Arcidæ can be made both simple and distinct, and will run in its briefest form as follows:—

Arcidæ include those integro-pallial dimyarian lamellibranchs, having a serrated hinge or hinge-line, which may be either straight, curved, or bent.

The following is the original diagnosis by Carpenter:—Shell regular, equivalve, with strong epidermis; ligament exterior, occupying an area between the beaks; hinge with a long row of similar comb-like teeth; pallial line distinct; muscular impressions sub-equal; structure corrugate, with vertical tubuli in rays between the ribs or striæ.

Many generic and sub-generic names have been given to species corresponding more or less with this description, and the following, excluding Leda, have been used for fossil species from Palæozoic rocks considered to belong to Arcidæ :—

Arca, by Linnæus, 1758.
Byssoarca, by Swainson, 1840.
Ctenodonta, by Salter, 1851.
Cucullæa, by Lamarck, 1801.
Cucullella, by McCoy, 1851.
Cyrtodonta, by Billings, 1858.
Davidia, by Hicks, 1872.
Glyptarca, by Hicks, 1872.
Lyrodesma, by Conrad, 1841.
Macrodon, by Lycett, 1845.
Matheria, by Billings, 1858.
Megambonia, by Billings, 1859.
Nucula, by Lamarck, 1799.
Palæarca, by Hall, 1859.
Tellinomya, by Hall, 1847.
Vanuxemia, by Hall, 1858.

Undoubted species of the family Arcidæ have also been assigned by various authors to genera of other families, such as Cleidophorus, Cypricardites, Pullastra, Actinodonta, etc.

Of the sixteen designations in the list of genera proposed for Palæozoic Arcidæ objection may be taken to the following :—

Byssoarca,
Cyrtodonta,
Davidia,
Lyrodesma,
Matheria,
Megambonia,
Tellinomya,
Vanuxemia.

The genus *Byssoarca* was founded by Swainson, on a character which must be admitted to be of very considerable importance, and sufficient in the estimation of most to entitle its possessors, apart from other considerations, to separate generic distinction. The byssal orifice is, however, a character common to species which may otherwise be considered typical Arcas and Macrodons. The retention of the genus Byssoarca would not, therefore, tend to that simplification of classification which is so desirable, and its absorption in the genera Arca and Macrodon may perhaps on these grounds be assented to.

Of *Cyrtodonta* it is sufficient to say that, as defined by Billings, it is quite equivalent to *Palæarca* of Hall, and as the latter name had priority, and is now generally used, the name *Cyrtodonta* may doubtless without objection be omitted from our lists.

The genus *Davidia,* which was established by Dr. Hicks on two species from the Tremadoc rocks of the neighbourhood of St. David's, was by the author placed in Arcidæ. I dissented from this at the time, and wrote :—" I fear I can scarcely agree with Dr. Hicks in this determination. Through the kindness of that gentleman I have had abundant opportunity of carefully examining the original specimens, and I do not find anything in either the form or the hinge line to justify Davidia being given to Arcidæ." This opinion is also supported by Professor Tryon and Dr. Fischer, who have not given Davidia a place amongst the Arcidæ.

The several American species described under the names *Megambonia* and *Vanuxemia,* by Billings and Hall, do not appear to possess characters sufficiently distinctive from those of *Palæarca* to justify the retention of either of those names.

Of *Matheria tenera* (Billings) it may be urged that not possessing posterior teeth it is entitled to be considered a separate genus; but no similar species has been yet found in our British rocks.

The name *Tellinomya* was given by Hall to a group of species which may with great propriety be placed in the genus *Ctenodonta*, and, indeed, in the original diagnosis it is difficult to find anything at variance with a description of typical species of *Ctenodonta.* The name is now, moreover, used for species of *Anatinidæ,* and it may therefore be eliminated from lists of *Arcidæ.*

With respect to *Lyrodesma,* I must venture to disagree with Prof. Tryon, who places this genus in *Arcidæ.* The distinctly trigonal form, and especially the radiating teeth of the hinge line, in my opinion, take it out of relationship with *Arca,* and ally it with the *Trigonidæ,* in which family it was placed by Woodward.

Neither does Prof. Tryon's exclusion of the genus *Nucula* from the *Arcidæ* appear to me to be justified, and still more must I object to its being allied with *Leda,* nor can I understand how this can consistently be done. The reason for the exclusion of *Leda* from the *Arcidæ,* this genus being sinu-pallial, must be equally potent against its alliance with the integro-pallial genus *Nucula,* yet it is sought to establish the family *Nuculidæ* to include *Leda* and other sinu-pallial genera. This to me appears like making a matter right, and then immediately after making it wrong again. It is true that the general form of *Nucula* differs from the Arcian type, but not so much so as that of *Lyrodesma,* which by the same author is placed in *Arcidæ,* or, indeed, as that of *Palæarca,* and, moreover, the nuculoid form is that of *Ctenodonta,* which every author includes in *Arcidæ.* If the existence of the cartilage-pit in the hinge line be deemed a sufficient cause for the exclusion of *Nucula* from alliance with

Arca, it will not suffice to ally it with *Leda*, which has a distinctly different pallial line, but will rather separate it from relationship with both genera. At present, however, I prefer to retain *Nucula* in *Arcidæ*, especially as there is only one species ascribed to the genus in our Palæozoic rocks, and that may possibly be a *Ctenodonta*.

With the eliminations for which reasons have been stated, and the retention of *Nucula*, the list of genera of *Arcidæ* represented in British Palæozoic rocks will be reduced to the following eight, arranged according to their affinities :—

Arca	*Cucullella*
Cucullæa	*Glyptarca*
Macrodon	*Palæarca*
Ctenodonta	*Nucula.*

(1.) ARCA, Linnæus.

Etym., *Arca*, a chest.

Shell equivalve or nearly so, thick, subquadrate, ventricose, strongly ribbed or cancellated ; margins smooth or dentated, close or sinuated ventrally ; hinge straight, teeth very numerous, transverse ; umbones anterior, separated by a flat, lozenge-shaped ligamental area, with numerous cartilage-grooves ; pallial line simple ; posterior adductor impression double ; pedal scars two, the posterior elongated.

The genus *Arca* restricted to those species having straight hinge-lines with both the anterior and the posterior teeth transverse, but including the Byssoarca of Swainson, or those having a byssal opening, is represented by about nine species in our Palæozoic rocks.

Though several species from Caradoc strata were named *Arca* by Portlock, no true *Arca* has yet been found lower than Ludlow rocks, the earliest being the *Arca primitiva* from the Ludlow of Freshwater East, figured and described by Prof. Phillips in the third volume of the 'Memoirs of the Geological Survey.'

The Silurian Arcas of Portlock appear on examination to properly belong, some to *Palæarca* and some to *Ctenodonta*, to the latter of which genera the *Arca Eastnori* of Sowerby and the *Arca subæqualis* of McCoy must be given.

Arca primitiva is the only Silurian species, nor do any appear in

Devonian rocks, and we do not find the genus well represented until the Carboniferous Limestone is searched, but from this formation eight species have been obtained.

The five so-called species of *Arca* from the Permian ascribed to *Arca striata*, *A. tumida*, *A. Loftusiana*, and *A. Kingiana* should all be included in *Macrodon*, since the posterior teeth of the hinge-line are horizontal.

Thus the genus *Arca* is represented in British rocks by one species in the Ludlow rocks and by nine species in the Carboniferous Limestone as follows:—

Distribution.

Ludlow.
  A. primitiva, Phill.
Carboniferous Limestone.
  A. cancellata, Mart.
  A. clathrata, McCoy.
  A. costellata, McCoy.
  A. fimbriata, McCoy.
  A. Lacordaireana, De Koninck.
  A. lanceolata, McCoy.
  A. reticulata, McCoy.
  A. semicostata, McCoy.
  A. obtusa, Phill.

(2.) Genus Cucullæa, Lamarck.

Etym., *Cucullus*, a cowl.

Shell sub-quadrate, ventricose; valves close, striated; hinge-teeth few and oblique, parallel with the hinge-line at each end; posterior muscular impression bounded by an elevated ridge.

Cucullæa is well characterized by the obliquity of the teeth and the posterior elevated ridge, which latter is an especially valuable feature for the identification of the genus, since it is one which casts distinctly indicate, the incision in the cast produced by the interior ridge not being easily obliterated.

This genus has not been found in rocks lower than the Middle Devonian, *Cucullæa amygdalina* of Phillips from the Marwood quarries being the earliest British species yet known. Some doubt must remain about this species, and also respecting the *C.*

Hardingii of Sowerby from the Upper Devonian in consequence of the interior not having been shown in the figures.

Six species from the Upper Devonian have been referred, three doubtfully, to *Cucullæa*; and five species from the Carboniferous Limestone complete the number of British Palæozoic species of this genus.

Distribution.

Middle Devonian.
 ? *C. amygdalina*, Phill. (Pal. Foss.).
Upper Devonian.
 ? *C. amygdalina*, Phill.
 C. angusta, Sow. (Geol. Trans.).
 ? *C. complanata*, Phill. (Pal. Foss. *Pullastra* sp.).
 C. depressa, Phill. (Pal. Foss.).
 ? *C. Hardingii*, Sow. (Geol. Trans.).
 C. trapezium, Sow. (Geol. Trans.).
Carboniferous Limestone.
 ? *C. amygdalina*, Phill.
 C. arguta, Phill. (*Arca*, sp. De Koninck).
 ? *C. Hardingii*, Sow.
 C. tenuistria, McCoy (Carb. Foss.).
 C. trapezium, Sow.

(3.) Genus MACRODON, Lycett.

Etym., μακρός, long, and ὀδούς, a tooth.

Shell thick, sub-rhomboidal, beaks anterior; hinge with a few oblique anterior teeth, and one or more long, laminar posterior teeth, parallel with the hinge-line.

These laminar teeth distinctly separate *Macrodon* from *Arca* and *Cucullæa*, both of which genera it resembles in outward form.

Though six so-called species referable to *Arcidæ* have been described from Permian rocks, there does not appear to be sufficient differentiation to justify the constitution of more than one species. The oldest of the six names, *striatus*, may be retained, and thus the *Macrodon striatus* will include the *Mytilites striatus* of Schlotheim and *Byssoarca striatus* of King, *B. tumida* (King), *B. Kingiana* (Verneuil), *B. antiqua* of Munster, *B. Loftusiana* (House), and the *Cucullæa sulcata* of Sowerby.

This species, *M. striatus*, is our only Palæozoic *Macrodon*, none appearing in rocks lower than the Permian.

Distribution.

Permian.
M. striatus, Schl. (*Byssoarca*, sp. King).
„ „ (*Mytilites*, sp. Schl.) (Ak. Münch.).
„ „ (*Cucullæa sulcata*, Sow.).
„ „ (*Byssoarca tumida*, King).
„ „ („ *Kingiana*, Vern., King).
„ „ („ *antiqua*, Munst., King).
„ „ („ *Loftusiana*, House, King).

(4.) Genus CTENODONTA, Salter.

Etym., κτείς, a comb, and ὀδούς, a tooth.

Shell elongately oval, subequilateral, smooth, or finely concentrically striate; valves moderately convex; hinge represented by two diverging comb-like denticulated margins without a special hinge-area between them and the beak, and below the latter, not interrupted by a pit; ligament apparently external, posterior to the beak.

This appears to have been the most important genus of *Arcidæ* in Palæozoic times, since 41 species of *Ctenodonta* have been recorded, while no other genus is represented by more than 14 species. *Ctenodonta* may be briefly described as *Nucula* without the cartilage pit in the hinge-line. The teeth are numerous and transverse, and the nuculoid form exists in all the species here included under *Ctenodonta.* The numerous species from Palæozoic rocks, originally described as *Nuculæ* by Phillips, McCoy, and others, have been divided between *Ctenodonta*, *Palæarca*, and *Leda*, with the exception of *Nucula Tateana*, of King, from the Permian.

The two Tremadoc species of *Ctenodonta* discovered by Dr. Hicks, *C. Menapiensis* and *C. Cambriensis*, extend the stratigraphical range of the genus into the Cambrian rocks.

Though the *Palæarca socialis* of Salter, from Arenig and Llandeilo strata, is not very fully figured or described, I am inclined to place it in *Ctenodonta* from its general form, reserving those species only, for the genus *Palæarca*, which have the posterior extremity greatly expanded. The removal of Portlock's and McCoy's Nuculas and Arcas to *Ctenodonta* give nine species of this genus to Caradoc or Bala strata, though one, *C. obliqua*, stated by Mr. Ruddy to occur in rocks of Bala age, near Corwen, is somewhat doubtful. Three appear in Lower Llandovery; seven in Upper Llandovery; two in Wenlock; and five in Ludlow rocks. The Devonian rocks have yielded five species.

In the Carboniferous Limestone the maximum development of *Ctenodonta* is found, 19 species having been described, but these, with one exception, were originally ascribed to *Nucula*; and two species are recorded from the Millstone Grit. Sowerby's *Nucula æqualis* and *N. accipiens* from the Coal Measures have also been given to *Ctenodonta.*

The large pebbles of the very interesting Budleigh Salterton Pebble Bed have yielded numerous fossils, showing the Palæozoic age of the original rock of which the pebbles are water-worn fragments, the bed itself being of Triassic age. Mr. Wyatt-Edgell described two species of lamellibranchs from these pebbles, which he ascribed to *Arcidæ*, and one of the two he named a *Ctenodonta.* The locality of the rock whence the pebbles came is doubtful, but their fossils seem to be Continental rather than British species, and it is considered by many that the pebbles are from the *Grès Armorician* of Brittany, in France, and of probably Arenig age. Mr. Pengelly, however, thinks they are from Cornish rocks, but as this is doubtful the species from the pebbles cannot with certainty be included in lists of British species other than as derived fossils in Triassic rocks.

Distribution.

Tremadoc.
- *C. Cambriensis*, Hicks (Q. J. G. S., Vol. xxix, p. 47, Pl. v).
- *C. Menapiensis*, Hicks (Q. J. G. S., Vol. xxix, p. 47, Pl. v).

Llandeilo.
- *C. socialis*, Salt.
- *C. varicosa*, Salt.

Caradoc.
- *C. ambigua*, Portl. (*Pectunculus* sp., Rep. Lond.).
- *C. lævis*, Sow. (*Nucula* sp., Silur. Syst.).
- *C. levata*, Hall.
- *C. obliqua*, Portl. (*Nucula* sp.).

C. regularis, Portl. (*Arca* sp., Rep. Lond.).
C. scitula, McCoy (*Arca* sp., Silur. Foss.).
C. subacuta, McCoy (*Nucula* sp., Silur. Foss.).
C. subtruncata, Portl. (*Arca* sp., Rep. Lond.).
C. transversa, Portl. (*Arca* sp., Rep. Lond.).
C. varicosa, Salt.

Lower Llandovery.
? *C. varicosa*, Salt.
C. psittacina, Salt., MS.

Upper Llandovery.
C. Anglica, D'Orb. (*Nucula* sp., Prod. Pal.).
C. deltoidea, Phill. (*Nucula* sp., Mem. Geol. Sur., Vol. ii).
C. Eastnori, Sow. (*Arca* sp., Silur. Syst.).
? *C. rhomboidea* Phill. (*Nucula* sp., Mem. Geol. Sur., Vol. ii).
C. subequalis, McCoy (*Arca* sp., Pal. Foss.).
C. subcylindrica, McCoy (*Nucula* sp., Silur. Foss.).
C. sulcata, His.

Wenlock.
C. Anglica, D'Orb.
C. interrupta, Brod.
C. sulcata, His.

Ludlow.
C. Anglica, D'Orb.
C. thracioides, Salt.
C. subequalis, McCoy.
C. sulcata, His.
C. obesa, Salt.

Lower Devonian.
C. Krachtæ, Roem.

Middle Devonian.
C. lineata, Phill. (*Nucula* sp., Pal. Foss.).

Upper Devonian.
C. antiqua, Sow.
C. latissima, Phill. (*Nucula* sp., Pal. Foss.).
? *C. lineata*, Phill.
? *C. plicata*, Phill. (*Nucula* sp., Pal. Foss.).
C. pullastriformis, McCoy (*Nucula* sp.) (*Pullastra antiqua*, Sow.).

Carboniferous Limestone.
C. antiqua, Sow. (*Pullastra* sp., Geol. Trans., Vol. v).

C. cuneata, Phill. (*Nucula* sp., Geol. York.).
C. attenuata, Flem. (*Nucula* sp., Carb. Foss.).
C. carinata, McCoy (*Nucula* sp., Carb. Foss.).
C. cylindrica, McCoy (*Nucula* sp., Carb. Foss.).
C. brevirostrum, Phill. (*Nucula* sp., Geol. York.).
C. delta, McCoy (*Nucula* sp., Carb. Foss.).
C. gibbosa, Flem. (*Nucula* sp., B. A.).
C. lævirostrum, Portl. (*Nucula* sp., Rep. Lond.).
C. lineata, Phill. (*Nucula* sp., Pal. Foss.).
C. longirostris, McCoy (*Nucula* sp., Carb. Foss.).
C. luciniformis, Phill. (*Nucula* sp., Geol. York.).
C. oblonga, McCoy (*Nucula* sp., Carb. Foss.).
C. palmæ, Sow. (*Nucula* sp., Min. Conch.).
C. rectangularis, McCoy (*Nucula* sp., Carb. Foss.).
C. stilla, McCoy (*Nucula* sp., Carb. Foss.).
C. tumida, Phill. (*Nucula* sp., Geol. York.).
C. undulata, Phill. (*Nucula* sp., Geol. York.).
C. uniliteralis, McCoy (*Nucula* sp., Carb. Foss.).

Millstone Grit.
C. gibbosa, Flem.
C. undulata, Phill.

Coal Measures.
C. æqualis, Sow. (*Nucula* sp., Geol. Trans., Vol. v).
C. accipiens, Sow. (*Nucula* sp., Geol. Trans., Vol. v).

(5.) Genus CUCULLELLA (McCoy).

Etym., diminutive of *Cucullæa.*

Shell thin, margins not crenulated, ligament external; no cartilage pit; teeth numerous, on a nearly straight cardinal line; anterior muscular scar bounded by a ridge; pallial line simple.

What *Cucullæa* is to *Arca*, so is *Cucullella* to *Ctenodonta*, *Cucullella* having a bent hinge-line and an interior ridge bounding one of the adductor muscular scars. In the case of this genus, however, the ridge bounds the anterior, not the posterior, scar as in *Cucullæa.*

The three species of Sowerby called *Cucullæa antiqua*, *C. ovata*, and *C. Cawdori* must be placed in *Cucullella*, and to these are now to be added *C. angulata* of Baily, and *C. coarctata* of Phillips. Three of these are in Caradoc or Bala strata; two, *C. antiqua* and *C. coarctata*, are recorded by Mr. Marr as occurring in rocks which appear to be of Lower Llandovery age; two are in Upper Llandovery rocks, and three in Ludlow beds.

No species of this genus having been described from Devonian, Carboniferous, or Permian rocks, it appears that *Cucullella* is confined to Silurian strata.

Distribution.

Caradoc.
  C. antiqua, Sow. (*Cucullæa* sp., Silur. Syst.).
  C. angulata, Baily.
  C. coarctata, Phill. (*Nucula* sp., Mem. Geol. Sur., Vol. ii).
Lower Llandovery.
  C. antiqua, Sow.
  C. coarctata, Phill.
Upper Llandovery.
  C. antiqua, Sow.
  C. ovata, Sow. (*Cucullæa* sp., Silur. Syst.).
Wenlock.
  C. ovata, Sow.
Ludlow.
  C. antiqua, Sow.
  C. Cawdori, Sow. (*Cucullæa* sp., Silur. Syst.).
  C. ovata, Sow.

(6.) Genus GLYPTARCA (Hicks).*

Etym., γλυπτός, carved, and *Arca*.

Inequilateral, strongly ventricose; beak near the anterior end, prominent, overhanging the hinge-line, more or less pointed at the extremity; two diverging ridges extend from the umbo to the margin, and enclose a triangular sulcus, having its base at the margin, which it thereby indents; anterior muscular impression strong, posterior less distinct; hinge-area narrow, plate thick, with three teeth in front of the umbo; surface strongly marked with growth lines.

---

* 'Quart. Journ. Geol. Soc.,' Vol. xxix, p. 48.

The last discovered genus of Palæozoic *Arcidæ*, *Glyptarca*, occurring as it does in the pre-Silurian Tremadoc rocks in great abundance, and in none other so far as we yet know, possesses considerable interest. It is to the important work of Dr. Hicks in South Wales that science is indebted for this addition to the family *Arcidæ*.

Glyptarca is characterized by a distinct anterior depression extending from the umbo to the ventral margin, and has thus a general resemblance to *Grammysia*, but that genus has two narrow sulci while *Glyptarca* has one only, which as it approaches the ventral margin considerably widens.

Of the two species described by Dr. Hicks, *G. primæva* is abundant in the Tremadoc rocks of Ramsey Island near St. David's, while the second species, which its author has done me the honour of naming after myself, is comparatively rare.

Distribution.

Tremadoc.

G. Lobleyi, Hicks (Q. J. G. S., Vol. xxix, p. 48, Pl. v).
G. primæva, Hicks (Q. J. G. S., Vol. xxix, p. 48, Pl. v).

(7.) Genus PALÆARCA (Hall).

Etym., παλαίος, ancient, and *Arca*.

Shell equivalve, inequilateral; umbones near the anterior end or terminal; general form obliquely tumid, transversely subrhomboidal ovate; posterior extremity larger than the anterior, and usually broadly rounded; two to eight oblique anterior teeth beneath, or a little in front of the umbones; two to four remote lateral teeth parallel with the hinge-line; pallial line simple; muscular scars two, anterior sometimes deeply excavated; posterior superficial; ligament external.

The exclusively Palæozoic genus *Palæarca* is characterized in its general form by the largeness of the posterior and the smallness of the anterior area, and the consequent obliquely tumid form of the whole. The teeth are not so numerous as in *Ctenodonta*, and the posterior teeth are oblique or almost parallel with the hinge-line.

The known range of *Palæarca*, like that of *Ctenodonta*, has been extended by Dr. Hicks, who has described two species, *P. Hopkinsoni* and *P. oboloidea*, from the Tremadoc rocks of Ramsey Island.

Mr. Salter described three species from Llandeilo strata, but one, the *P. socialis*, having been removed to *Ctenodonta*, two species only appear to occur in those rocks, while seven are recorded from the Caradoc.

Not only is *Palæarca* essentially Palæozoic, but, like *Cucullella* and *Glyptarca*, it is confined to strata below the Devonian, two species in the Upper Llandovery, and one, *P. Edmondiiformis*, in the Upper Ludlow, being the latest representatives of the genus *Palæarca*.

Distribution.

Tremadoc.
  P. Hopkinsoni, Hicks (Q. J. G. S., Vol. xxix, p. 48, Pl. v).
  P. oboloidea, Hicks (Q. J. G. S., Vol. xxix, p. 48, Pl. v).
Arenig.
  P. amygdalus, Salt. (Mem. Geol. Sur., Vol. iii).
Llandeilo.
  P. amygdalus, Salt.
  P. Billingsiana, Salt. (Mem. Geol. Sur., Vol. iii).
Caradoc.
  P. Billingsiana, Salt.
  P. Bulla, Salt. (Mem. Geol. Sur., Vol. iii).
  P. dissimilis, Portl. (*Arca* sp., Rep. Lond.).
  P. Edmondiiformis, McCoy (*Arca* sp., Pal. Foss.).
  P. modiolaris, Salt. (Mem. Geol. Sur., Vol. iii).
  P. obliqua, Portl. (*Arca* sp., Rep. Lond.).
  P. obscura, Salt. (Mem. Geol. Sur., Vol. iii).
  P. quadrata, Salt. (Mem. Geol. Sur., Vol. iii).
Llandovery.
  P. lingualis, Phill. (*Nucula* sp., Mem. Geol. Sur., Vol. ii).
Upper Ludlow.
  P. Edmondiiformis, McCoy.

(8.) Genus Nucula, Lamarck.

Etym., diminutive of *Nux*, a nut.

Shell trigonal, with the umbones turned towards the short posterior side; smooth or sculptured, epidermis olive, interior pearly, margins crenulated; hinge with prominent internal cartilage-pit, and a series of sharp teeth on each side; pallial line simple.

A greater number of Palæozoic *Arcidæ* have been originally described under the name of *Nucula* than under any other generic designation, and yet, with one exception, all have been assigned to other genera. It is true that in several of these species there is not direct evidence for removing them from *Nucula*, but when it is found that every Palæozoic nuculoid species in which the hinge-line has been fully seen is a *Ctenodonta*, those species the hinge-line of which is not yet known may more fairly be given to *Ctenodonta* than to *Nucula*. The majority of the others have been assigned to *Leda* since they have the peculiar extension of the posterior extremity so characteristic of that genus, while no contradictory internal characters have been noticed.

Whether *Nucula Tateiana*, of King, from the Permian, is or is not a true *Nucula* it is difficult to ascertain, inasmuch as Prof. King discovered the species after the plates for his monograph were ready, and there is, therefore, no published figure. The diagnosis is very brief and incomplete, leaving untold that which is necessary to be known. The author, however, writes of the species as a true *Nucula*, and on this testimony from so competent an observer as Prof. King it has been allowed to remain.

The genus *Nucula* is represented, therefore, in British Palæozoic rocks by but one species, the *N. Tateiana* which Prof. King obtained from the Permian Magnesian Limestone of Humbleton Hill, Durham.

Distribution.

Permian.

N. Tateiana, King (Perm. Foss.)

Thus it appears that the total number of species of the family *Arcidæ* occurring in British Palæozoic rocks so far as is yet known is 88, with a stratigraphical distribution as follows :—

Tremadoc, 6 ; Arenig, 2; Llandeilo, 4 ; Caradoc, 21 ; Lower Llandovery, 4 ; Upper Llandovery, 10; Wenlock, 4 ; Ludlow, 10 ; Lower Devonian, 1 ; Middle Devonian, 2 ; Upper Devonian, 11 ; Carboniferous Limestone, 33; Millstone Grit, 2 ; Coal Measures, 2 ; Permian, 2. But it is right to add that some authors recognize as distinct species several forms here regarded as varieties.

Upwards of thirty years ago Professor Phillips drew attention to the fact that the earliest families of the Lamellibranchiata were *Arcidæ* and *Mytilidæ*. This still appears to be true, as all the lamellibranchs since discovered in Cambrian rocks are assignable to those two families.

TABLE SHOWING STRATIGRAPHICAL DISTRIBUTION OF BRITISH FOSSIL ARCIDÆ.

	Tremadoc.	Arenig.	Llandeilo.	Caradoc, Bala.	L. Llandovery	U. Llandovery.	Wenlock.	Ludlow.	L. Devonian.	M. Devonian.	U. Devonian.	L. Carboniferous and Carbon. Limest.	Millstone Grit.	Coal Measures.	Permian.
ARCA.															
A. cancellata, Mart. ...												×			
A. clathrata, McCoy ...												×			
A. costellata, McCoy ...												×			
A. fimbriata, McCoy ...												×			
A. Lacordaireana, De Kon.												×			
A. lanceolata, McCoy ...												×			
A. obtusa, Phill. ...												×			
A. primitiva, Phill. ...								×							
A. reticulata, McCoy ...												×			
A. semicostata, McCoy												×			
CUCULLÆA.															
C. amygdalina, Phill. ...										×	×	×			
C. angusta, Sow. ...											×				
C. arguta, Phill. ...												×			
C. complanata, Phill. ...											×				
C. depressa, Phill. ...											×				
C. Hardingii, Sow. ...											×	×			
C. tenuistria, McCoy ...												×			
C. trapezium, Sow. ...											×	×			
MACRODON.															
M. striatus, Schl. ...															×
CTENODONTA.															
C. accipiens, Sow. ...														×	
C. æqualis, Sow. ...														×	
C. ambigua, Portl. ...				×											
C. Anglica, D'Orb. ...						×	×	×							
C. antiqua, Sow. ...											×	×			
C. attenuata, Flem. ...												×			
C. brevirostrum, Phill....												×			
C. Cambriensis, Hicks ...	×														
C. carinata, McCoy ...												×			
C. cuneata, Phill. ...												×			

	Tremadoc.	Arenig.	Llandeilo.	Caradoc, Bala.	L. Llandovery.	U. Llandovery.	Wenlock.	Ludlow.	L. Devonian.	M. Devonian.	U. Devonian.	L. Carboniferous and Carbon. Limest.	Millstone Grit.	Coal Measures.	Permian.
CTENODONTA (*continued*).															
C. cylindrica, McCoy												×			
C. delta, McCoy												×			
C. deltoidea, Phill.						×									
C. Eastnori, Sow.						×									
C. gibbosa, Flem.												×	×		
C. interrupta, Brod.							×								
C. Krachtæ, Roem.									×						
C. lævirostrum, Portl.												×			
C. lævis, Sow.				×											
C. latissima, Phill.											×				
C. levata, Hall				×											
C. lineata, Phill.										×	×	×			
C. longirostris, McCoy												×			
C. luciniformis, Phill.												×			
C. Menapiensis, Hicks	×														
C. obesa, Salt.								×							
C. obliqua, Portl.				×											
C. oblonga, McCoy												×			
C. palmæ, Sow.												×			
C. plicata, Phill.											×				
C. psittacina, Salt. MS.					×										
C. pullastriformis, McCoy											×				
C. rectangularis, McCoy												×			
C. regularis, Portl.				×											
C. rhomboidea, Phill.						×									
C. scitula, McCoy				×											
C. socialis, Salt.		×	×												
C. stilla, McCoy												×			
C. subacuta, McCoy				×											
C. subæqualis, McCoy						×		×							
C. subcylindrica, McCoy						×									
C. subtruncata, Portl.				×											
C. sulcata, His.						×	×	×							
C. thracioides, Salt.								×							
C. transversa, Portl.				×											
C. tumida, Phill.												×			
C. undulata, Phill.												×	×		
C. uniliteralis, McCoy												×			
C. varicosa, Salt.			×	×	×										

	Tremadoc.	Arenig.	Llandeilo.	Caradoc, Bala.	L. Llandovery.	U. Llandovery.	Wenlock.	Ludlow.	L. Devonian.	M. Devonian.	U. Devonian.	L. Carboniferous and Carbon. Limest.	Millstone Grit.	Coal Measures.	Permian.
CUCULLELLA.															
C. angulata, Baily	...	...	...	×											
C. antiqua, Sow.	...	...	...	×	×	×	...	×							
C. Cawdori, Sow.	...	...	...	...	...	...	...	×							
C. coarctata, Phill.	...	...	...	×	×										
C. ovata, Sow.	...	...	...	...	...	×	×	×							
GLYPTARCA.															
G. Lobleyi, Hicks	×														
G. primæva, Hicks	×														
PALÆARCA.															
P. amygdalus, Salt.	...	×	×												
P. Billingsiana, Salt.	..	...	×	×											
P. bulla, Salt.	...	...	...	×											
P. dissimilis, Portl.	...	...	...	×											
P. Edmondiiformis, McCoy ...	...	...	...	×	...	...	...	×							
P. Hopkinsoni, Hicks	×														
P. lingualis, Phill.	...	...	...	...	...	×									
P. modiolaris, Salt.	...	...	...	×											
P. obliqua, Portl.	...	...	...	×											
P. oboloidea, Hicks	×														
P. obscura, Salt.	...	...	...	×											
P. quadrata, Salt.	...	...	...	×											
NUCULA. ?															
N. Tateiana, King	...	...	...	...	...	...	...	...	...	...	...	...	...	...	×

NOTES ON PTERODACTYLS.

By E. T. NEWTON, F.G.S.

The first discovery of a Pterodactyl seems to have been made a little more than a hundred years ago, for the earliest record which we have is that by Collini in the year 1784,* when he described the remains of an "unknown marine animal" from the Lithographic Slates. To this specimen Cuvier, in the year 1809,† gave the generic name of *Pterodactylus*; and Sömmerring, in 1812,‡ called it *Ornithocephalus antiquus*. Cuvier, in 1824, however, renamed it *Pterodactylus longirostris*,§ and this name has since been very generally used, although Sömmerring's specific name of *antiquus*, having priority, must be adopted.

The most remarkable peculiarity of this fossil, which may be taken as the type of all Pterodactyls, is seen in the structure of the hand; the outer digit being formed by four enormously elongated phalanges, and these, as we now know, supporting an expansion of the integument resembling the patagium of a bat; hence it is not surprising to find that some writers have thought the Pterodactyls near allies of those aberrant mammals. (See figs. 8 and 9.)

The skull of the Pterodactyl has a very bird-like appearance, although its intimate structure more resembles that of a lizard. The possession of teeth, which at one time was thought to be an unbird-like character, we now know to be also distinctive of the American Cretaceous birds. Upon the sides of the Pterodactyl skull three vacuities are to be seen, namely, the orbit, the nasal aperture, and, between these, a third, which is known as the preorbital fossa.

Since the beginning of the present century many works on Pterodactyls have been published, and one may notice, as perhaps the most important among them, Prof. Hermann von Meyer's 'Reptilien aus dem Lithographischen Schiefer,' forming part of his classical 'Fauna der Vorwelt;' Sir Richard Owen's numerous contributions, chiefly published in the Palæontographical Society's volumes; and Prof. H. G. Seeley's writings, more especially his

---

* 'Acta Acad. Theod. Palat.,' Vol. v, p. 58.

† 'Ann. d. Mus.,' Vol. xiii, p. 424.

‡ 'Denkschr. k. bayr. Ak. München,' Vol. iii, p. 126.

§ 'Ossm. Foss.,' ed. 3, Vol. v, Pt. ii, p. 359.

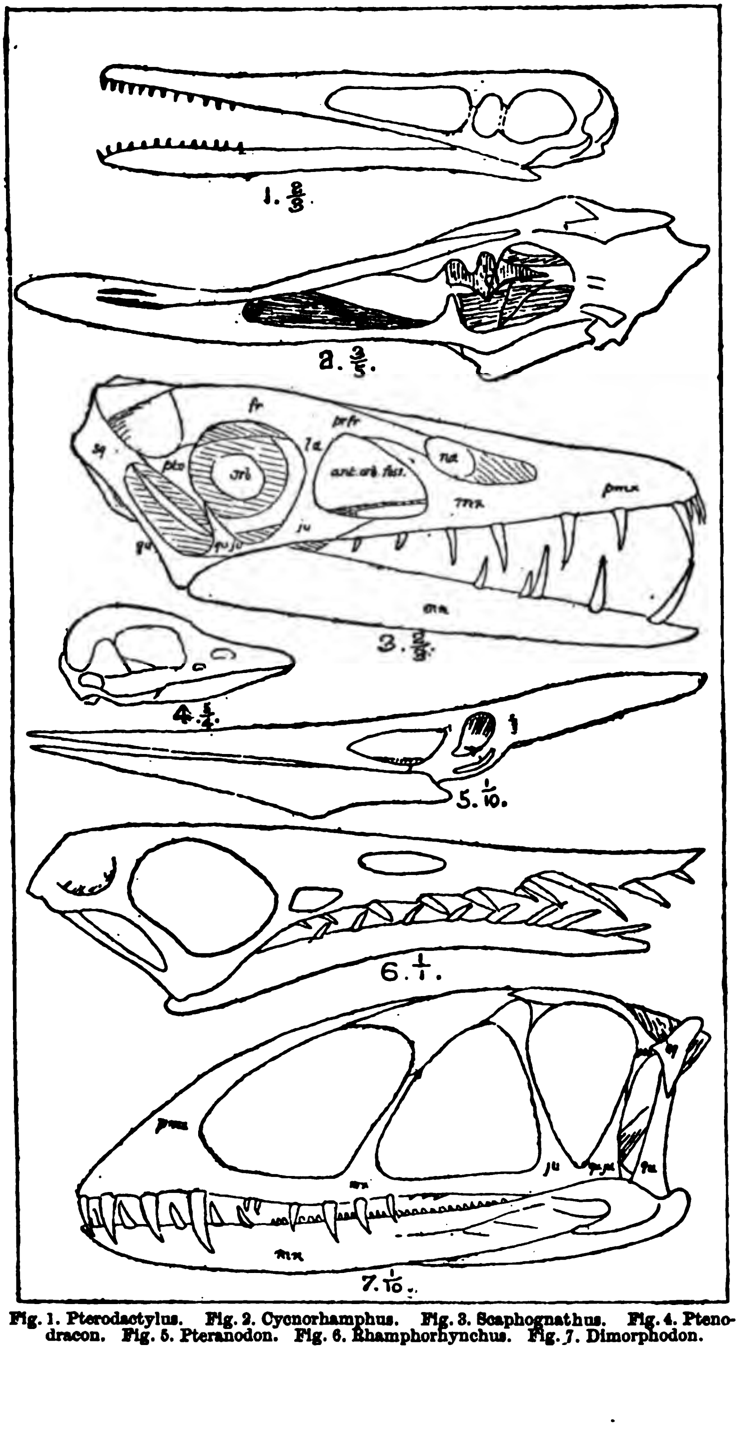


Fig. 1. Pterodactylus. Fig. 2. Cycnorhamphus. Fig. 3. Scaphognathus. Fig. 4. Ptenodracon. Fig. 5. Pteranodon. Fig. 6. Rhamphorhynchus. Fig. 7. Dimorphodon.

'Ornithosauria,' in which is given a good bibliography. Prof. Zittel's 'Ueber Flugsaurier aus dem Lithographischen Schiefer Bayerns'* and Prof. Marsh's descriptions of the American Pterodactyls † may also be noticed as being among the latest contributions to the history of *Ornithosauria.* No less than twenty-seven generic names have been given to Pterodactyls, and these have included a large number of species; but fortunately the work of reduction has already begun, and only fourteen genera with eighty-six species are now acknowledged, and many of these rest on very slight foundations.

It is proposed in the following pages to notice briefly each of these genera, and to point out some of the characters by which they are distinguished; but before doing so I desire to acknowledge my indebtedness to Mr. R. Lydekker, who has most courteously allowed me to see the proof sheets of his 'Catalogue of the Fossil Reptiles in the British Museum,' and from this I have derived much assistance in putting together these notes.

PTERODACTYLUS (Cuvier, 1809). (Fig. 1.) The *Pterodactylus antiquus* above referred to may be taken as the type of this genus, which is distinguished by the following characters:—The three lateral apertures of the head are only partially separated from each other by bone. The jaws are toothed to their anterior extremities. The head is elongated. The neck is long. The tail short. Hind legs long. Ilium narrow, extending far in front of acetabulum; ischium extending behind the acetabulum; pubic bone short, rounded, and without a bony symphysis. (See figs. 8 and 9.)

Pterodactylus has been chiefly found in the Lithographic Slates of Germany; but *P. liassicus* has been recorded from the Keuper and Upper Lias of Germany, and other species from the Lias, Wealden, and Kimeridge Clay of Britain.

The species of Pterodactylus are mostly small or of moderate size, varying from, perhaps, the size of a blackbird to that of a goose, some of the smaller ones having a head a little less than two inches long and an expanse of wing about 16 inches; while one of the large species had a head eight inches long, and, if the wings were in proportion, they must have extended at least 60 inches.

CYCNORHAMPHUS (Seeley, 1870). (Fig. 2.) In the year 1854 Prof.

---

* 'Palæontographica,' Vol. xxix, p. 49, 1882.

† 'Amer. Journ. Sci.,' 1871-84.

Quenstedt* made known the occurrence of a Pterodactyl in Würtemberg, which he alluded to as the first *Pterodactylus Württembergicus*, and subsequently named *Pterodactylus suevicus*,† the name *P. Württembergicus*, as he explained,‡ not being used by him

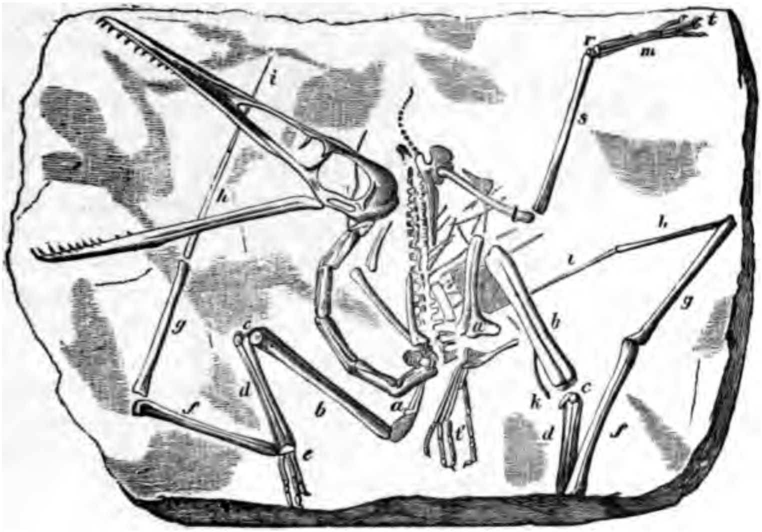


FIG. 8.—*Pterodactylus antiquus*, from the Lithographic Slate, Bavaria. About half natural size. *a*, humerus; *b*, radius and ulna; *c*, carpus; *d*, metacarpus; *r*, clawed digits; *f*, *g*, *h*, *i*, phalangeals of ulnar digits; *k*, rib; *l*, femur; *s*, tibia; *t*, tarsus; *m*, metatarsals; *t*, phalangeals of pes. (This and the following figures are taken from the 'Catalogue of Fossil Reptilia in the British Museum,' 1888, by kind permission of the Trustees.)

specifically, but merely to indicate that it was the first Pterodactyl found in Würtemberg. The skull of this specimen was somewhat crushed, and apparently on account of this two apertures were visible on the upper and front part of the beak, which were thought to be nasal apertures, and, if this interpretation were correct, made the skull quite unlike any other Ornithosaurian. Prof. Seeley, chiefly because of this supposed difference in the position of the nasal apertures, proposed to place the species in a distinct genus, which he named *Cycnorhamphus*,[*] and gave as its chief characters—" Nares very small, and looking upwards from a swan-like beak. Middle hole of the skullvery large and elongated, and lateral. Neck long. Wing-metacarpal long. Four joints in the wing-finger. Ilium widening in front. Epipubic bones (pubes) meeting mesially." An examination of the figures given by Prof. Quenstedt, and of another specimen more recently described by Dr. Fraas,[†] leads me to think that the skull of *P. suevicus* is formed on precisely the same plan as in other species referred to

---

* 'Neues Jahrb.,' 1854, p. 570.
† 'Ueber *Pterodactylus suevicus* in Lithog. Schief, Tubingen, 1855.
‡ 'Der Jura,' p. 812, 1858.

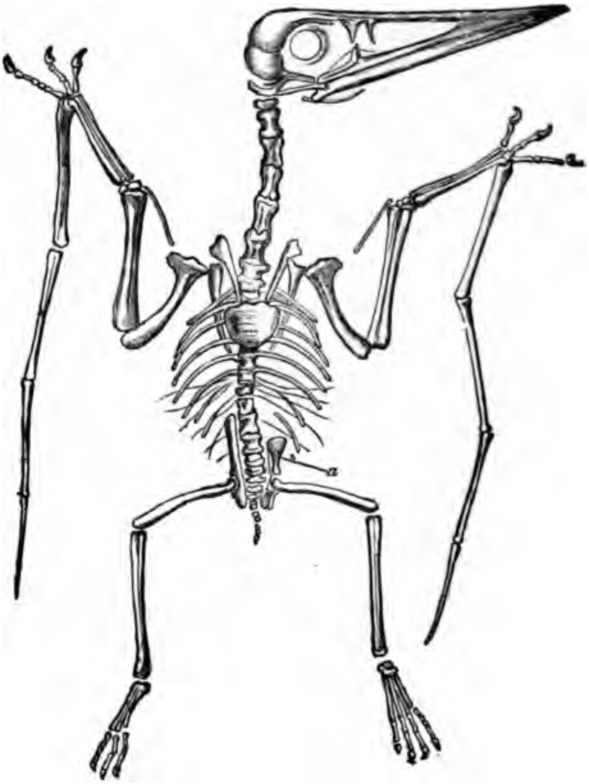


FIG. 9.—*Pterodactylus spectabilis*, from Lithographic Slate, Bavaria. Natural size. *a*, left pubis (prepubis); on the opposite side the ilium is exposed.

---

[*] 'Ornithosauria,' p. 111, 1870.

[†] 'Palæontographica,' Vol. xxv, p. 163, 1878.

the genus *Pterodactylus;* that the openings on the upper part of the snout are due to the crushing, which has opened the suture at the side of the premaxillary process; and that the large anterior portion of the side opening is really the nasal opening, which is not altogether separated from the pre-orbital fossa, although processes from the frontal region indicate the boundaries between the three apertures.

Mr. R. Lydekker, in his 'Catalogue of Fossil Reptiles,' has kept *Cycnorhamphus* distinct from *Pterodactylus*, believing that other characters of the skeleton justify its separation; but its generic distinctness seems to me doubtful.

This genus, which contains but one species, *C. suevicus*, is only known from the Lithographic Slates.

The length of the head is about six inches in the original specimen, and about nine inches in that described by Dr. Fraas.

PTENODRACON (Lydekker, 1888). (Fig. 4.) This name is proposed by Mr. R. Lydekker* for the small Pterodactyl first specifically named by Sömmerring *brevirostris*, and placed by him in his genus *Ornithocephalus*.† By most other writers, however, this interesting little form has been called *Pterodactylus*. Prof. Seeley, thinking it desirable to keep the species generically distinct, proposed to retain Sömmerring's genus for it alone; but Prof. Zittel ‡ has shown that the name *Ornithocephalus* cannot be thus used, and Mr. Lydekker has therefore introduced the name of *Ptenodracon*, suggesting that *P. Meyeri* should be included in the same genus with *P. brevirostris*.

Ptenodracon has a short skull, and its muzzle is not produced into a rostrum. Judging from the figures given by Sömmerring,§ Cuvier,‖ and Goldfuss¶ the nasal aperture is separated by bone from the pre-orbital fossa; but both these apertures are small, more especially the latter. The neck is short.

This is the smallest Pterodactyl known, being about the size of a sparrow, the head measuring little more than an inch in length. It is only known from the Lithographic Slate.

SCAPHOGNATHUS (Wagner, 1861). (Fig 3.) *Pterodactylus crassi-*

---

* 'Catalogue of the Fossil Reptiles in the British Museum,' p. 4.

† 'Denkschr. k. bayr. Ak. München,' Vol. vi, p. 89, 1816-17.

‡ 'Palæontographica,' Vol. xxix, p. 80, 1882.

§ *Loc. cit.*

‖ 'Ossm. Foss.,' ed. 3, Vol. v, Pt. ii, Pl. 23, Fig. 7.

¶ 'Nova Acta Leop. Ak.,' Vol. xv, Pt. i, 1831.

rostris from the Lithographic Slate is the type of this genus, and till quite recently, was the only known species. It was described and figured by Dr. Goldfuss in the year 1831,* and the excellent restoration was reproduced by Dr. Buckland in his 'Bridgewater Treatise' in 1836; indeed, on account of the perfection of the specimen, and in part, perhaps, because of the beautiful figures and restorations of it which were published, it has often been reproduced and taken as the type of Pterodactyl structure. The five digits to the hand represented by Dr. Goldfuss are now known to be incorrect, there being only four digits, three with claws and the long outer one which supported the patagium. This specimen differs in several ways from the true *Pterodactylus*, and most writers have agreed as to the propriety of placing it in a separate genus. In 1843 Prof. Fitzinger † proposed to call the genus *Pachyrhamphus*, and Prof. Seeley adopted this name in 1870 ; ‡ but as the same name had been used by Dr. Gray in 1840 for a genus of birds, it could not be retained for the Pterodactyl. In 1852 Dr. Giebel § used the name of *Brachytrachelus*, but this also, was preoccupied by a genus of Coleoptera. It was not until the year 1861 that Dr. Wagner ‖ proposed the name of *Scaphognathus*, which is the generic term now to be adopted for Goldfuss' *P. crassirostris*. (See fig. 10.)

Scaphognathus is characterized by its massive skull, which has the three lateral apertures of moderate size, and completely separated by bony bars, the nasal opening being the smallest and the orbit the largest of the three : the teeth extend to the ends of the jaws, and are subequal in size : the neck is short and thick; and the tail is unknown.

It may perhaps be well to call attention to another example of *Scaphognathus*, representing a new species, which has recently been described,¶ because it throws additional light on the structure of the skull of this genus in particular, and on that of the *Pterosauria* in general. The specimen was obtained by the Rev. D. W. Purdon, of Wolverhampton, from the Upper Lias of Lofthouse, near Whitby. It is about five-and-a-half inches long, but has lost, perhaps, two inches of the front of the snout. The various bones of the skull are better shown than in any Pterosaurian hitherto discovered. The base is remarkable for its great depth and flattening from before backwards, as well as for the pair of long basi-pterygoid processes, which pass down to the inner angle of the large quadrate. The palatine and pterygoid bones are united into one bar, and anteriorly this forms the hinder boundary of the internal nostril, which is completely surrounded by bone, and placed far forwards. The back of the skull exhibits a pair of wing-like par-occipital processes closely resembling those found in some lizards, and, indeed, the structure of the entire skull closely resembles that of a lizard.

---

* 'Nova Acta Leop. Ak.,' Vol. xv, Pt. i, p. 63.
† 'Systema Reptilium,' p. 35.
‡ 'Ornithosauria,' p. 111.
§ 'Allgemeine Palæontologie,' p. 231.
‖ 'Sitz. k. bayr. Ak. München,' Vol. i, p. 519.
¶ 'Royal Soc. Proc.' Vol. 43, p. 436 (1888).

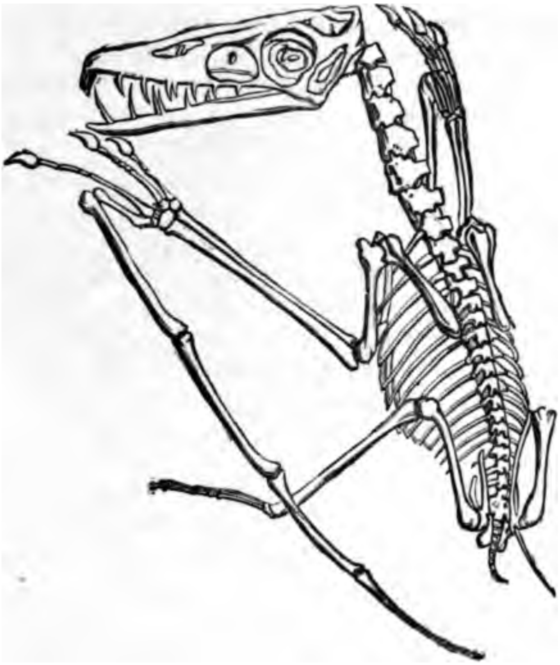


FIG. 10.—*Scaphognathus crassirostris*, from the Lithographic Slate, Bavaria. One-third natural size. This figure is somewhat restored.

By carefully cutting away the frontal and parietal regions of the left side, a cast of one-half of the brain has been exposed, and this proves to be very small in proportion to the skull. In this particular, therefore, it resembles the brain of a reptile; but in its structure it shows a greater affinity to that of birds. The cerebral lobe is oval in shape, and directly behind it, on the side of the brain, there is a large optic lobe, which, although extending to the upper surface, does not meet its fellow of the opposite side, as is the case in all reptiles, but seems to have been separated from it by the forward extension of the cerebellum, in a manner similar to that which occurs in birds. The peculiar lobe of nervous matter found at the side of the medulla in birds, and known as the flocculus, is present in this Pterodactyl, but does not occur in reptiles. The American toothed-bird, *Hesperornis*, had a brain very closely resembling that of the Pterodactyl, although proportionately rather larger.

This Yorkshire fossil gives us some information as to the auditory organ of the Pterosauria. In close relation to the flocculus, portions of three semicircular canals have been uncovered which agree so closely in position with the bony semicircular canals of the bird's auditory apparatus, that there can be no doubt as to their having been of a similar nature. The fenestra ovalis has been found similarly placed to that of the chameleon; and this fact, together with the form and position of the quadrate bone, leads to the conclusion that, like the chameleon, this Pterodactyl had no ear drum.

Scaphognathus is at present represented by two species, *S. crassirostris*, Goldfuss, from the Lithographic Slates of Bavaria, and *S. Purdoni*, Newton, from the Upper Lias of Lofthouse, near Whitby. The skull of the first specimen measures about five inches in length, that of the second about 7·5 inches; and, judging from other Pterodactyls, the expanse of wings would probably be in the first nearly three feet, and in the second perhaps four feet.

DIMORPHODON (Owen, 1858). (Fig. 7.) Pterodactyl remains from the Lower Lias of Lyme Regis were described by Dr. Buckland in 1829 * as *Pterodactylus macronyx;* but it was not until the year 1858 that parts of the skull were made known by Sir R. Owen,† and named generically *Dimorphodon.* In 1870 a still more perfect specimen was described by the same author in his 'Reptiles of the Lias Formations.'[*]

---

* 'Proc. Geol. Soc.,' Feb. 6, 1829.

† 'Brit. Assoc. Rep. for 1858,' p. 97 (1859), and 'Phil. Trans.,' Vol. 149, p. 161 (1859).

This genus is characterized by having the front teeth in both jaws large, and extending to their anterior extremities; but in the mandible the hinder teeth are very small. The lateral apertures of the skull are very large, and distinctly separated by slender bony bars. The tail is long and stiff, and the hind limbs are long. Length of head nearly nine inches, and the stretch of wings perhaps 70 inches. (See fig. 11.)

Dimorphodon is represented by but one species, and is only known from the Lias of Lyme Regis.

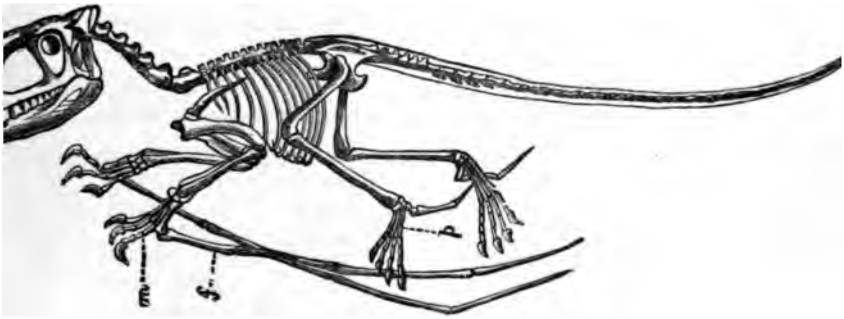


FIG. 11.—*Dimorphodon macronyx*, from the Lower Lias, Lyme Regis. One-seventh natural size. Restored.

RHAMPHORHYNCHUS (H. v. Meyer, 1846). (Fig. 6.) Prof. H. v. Meyer[†] proposed this name for certain Pterodactyls from the Lithographic Slate having the extremities of the jaws devoid of teeth, and probably, when alive, covered with a horny sheath. In addition to this the teeth are all directed obliquely forwards, and the three lateral apertures of the skull are separated by bony bars, the nasal aperture being of moderate size, and the pre-orbital fossa small. The scapula and coracoid seem to be united. The tail is long and stiff, being supported by a number of bony splints, or ossified tendons. The hind limbs are short: the pubes are narrow, elongated, and bent, uniting in a bony symphysis: the ischium is ankylosed to the ilium; and the sacrum has from three to five vertebræ. (See fig. 12.)

---

[*] Palæont. Soc. Vol. for 1869.

[†] 'Palæontographica,' Vol. i.

The length of the skull in different species varies from somewhat less than two inches to rather more than eight inches, and this probably indicates a stretch of wings of from one foot to perhaps four feet.

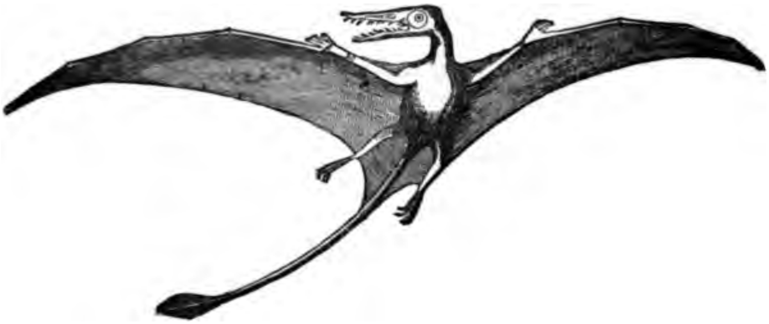


FIG. 12.—*Rhamphorhynchus Münsteri.* Restored (after Marsh).

RHAMPHOCEPHALUS (Seeley, 1880). So far back as the year 1832, Prof. H. v. Meyer* named certain Pterodactyl remains from the Stonesfield Slate *Pterodactylus Bucklandi*, and in 1859 Prof. Huxley† described additional specimens which he referred to the genus *Rhamphorhynchus*, distinguishing two species; one the *R. Bucklandi* of V. Meyer, the other a new form, for which he suggested the name *R. depressirostris*. Prof. Seeley, in 1880,‡ described part of a skull which he named *R. Prestwichi*, and proposed to include all the Stonesfield Slate Pterodactyls in a new genus, *Rhamphocephalus*, which he distinguished from *Rhamphorhynchus* by the great length of the skull behind the orbits, and its constriction between the orbits. The anterior mandibular teeth are larger than the posterior, and are directed nearly vertically. The scapula and coracoid are united. The skull of *R. Prestwichi* was about four and a half inches long.

This genus, as at present understood, includes all the Stonesfield Slate Pterodactyls, and one from the Great Oolite of Sarsden.

DORYGNATHUS (Wagner, 1861). In the year 1830 some portions of a Pterodactyl were described by Theodori* from the Upper Lias of Banz, near Boll, as *Ornithocephalus Banthensis*; and, before the skull of *Pterodactylus macronyx*, Buckland (now *Dimorphodon*), was known, Prof. H. v. Meyer† referred the Banz specimen to Buckland's species, calling both *Pterodactylus macronyx.* The jaws from Banz were known to have edentulous terminations, and consequently, when the genus *Rhamphorhynchus* was established, Theodori referred his *P. macronyx* to it.‡ When the skull of *Dimorphodon macronyx* was described by Sir R. Owen § it was obviously different from Theodori's specimen, and deserving of generic distinction. Dr. Wagner, in 1860,‖ proposed for the Banz specimen the name *Dorygnathus*, which, he said, differed from *Rhamphorhynchus* in having the under part of the front of the lower jaw forming a wing-like expansion. The scapula and coracoid seem to have been united. The length of the skull was probably about six inches, the lower jaw measuring somewhat more than five inches.

---

* 'Palæologica,' p. 117.

† 'Quart. Journ. Geol. Soc.,' Vol. xv, p. 658.

‡ 'Quart. Journ. Geol. Soc.,' Vol. xxxvi, p. 27.

Dorygnathus is only represented by the one species and that is from the Upper Lias of Banz.

ORNITHOCHEIRUS (Seeley, 1869). Dr. Mantell, in the year 1827,¶ described some fossil bones from the Wealden of Hastings as parts of a bird, and in 1844** named them *Palæornis Cliftii.* Sir Richard Owen, in 1840,†† described some bones from the Chalk of Kent as those of a bird allied to the albatross, and in 1846 ‡‡ he named them *Cimoliornis diomedeus.* Afterwards he showed that Dr. Mantell's specimen from the Wealden§§ and his own specimens from the Chalk ‖‖ were really remains of Pterodactyls. Prof. Seeley, in 1870, proposed to use the new generic term of *Ornithocheirus* for the numerous Pterodactyl remains which had been found in the Cambridge Greensand. All the remains of these creatures which have been obtained from British Cretaceous Rocks are very fragmentary, and Mr. R. Lydekker proposes, and I think wisely, to include them for the present in one genus—Prof. Seeley's *Ornithocheirus*—the earlier names of *Palæornis* and *Cimoliornis* being inappropriate. On account of the fragmentary condition of the specimens the characters of the genus are not very satisfactory, but the following have been given as distinctive:—The teeth of the upper jaw are prolonged anterior to the muzzle: the palate has a longitudinal ridge, and the symphysis of the lower jaw a corresponding groove. The skull may be short or produced into a long rostrum. Some species are thought to have only three digits to the manus, and some, at least, appear to have had a long tail. The sacrum consists of not fewer than three vertebræ.

---

* 'Frorieps Notizen,' No. 623.

† 'Nova Acta Leop. Ak.,' Vol. xv, Pt. ii, p. 198, 1831.

‡ 'Bericht d. naturf. Vereins in Bamberg,' 1852, p. 17.

§ 'Brit. Assoc. Rep. for 1858,' p. 97, and 'Phil. Trans.,' Vol. 149, p. 161 1859.

‖ 'Sitz. k. bayr. Ak, München,' 1860, p. 48, and 1861, p. 520.

¶ 'Fossils of Tilgate,' p. 81.

** 'Medals of Creation,' p. 806.

†† 'Trans. Geol. Soc.,' Ser. ii, Vol. vi, p. 411.

‡‡ 'Brit. Foss. Mam. and Birds,' p. 545.

§§ 'Quart. Journ. Geol. Soc.,' Vol. ii, p. 96, 1846.

‖‖ 'Proc. Zool. Soc.,' 1851, p. 28.

The genus *Ornithocheirus* as now constituted includes many species, but the imperfection of the specimens makes it probable that the number will have to be reduced. On the other hand, it seems likely that the acquisition of better examples will show the necessity of again increasing the number of genera.

Some of the Cretaceous forms were the largest representatives of the *Ornithosauria* on this side of the Atlantic. *Ornithocheirus Cuvieri* probably had an expanse of wings of not less than 18 feet.

Species of *Ornithocheirus* are known in Britain from the Purbecks to the Upper Chalk inclusive, and *O. compressirostris*, which has a wide range in England, has been recorded by Prof. H. v. Meyer from the Portland Beds of Solothurn.

ORNITHOSTOMA (Seeley, 1871). Prof. Seeley proposed this name provisionally in 1871* for three portions of Pterodactyl snouts from the Cambridge Greensand which "appear to be entirely destitute of teeth." If this character should prove to be correct, then the relation of this genus to the toothless *Pteranodon* of North America will become a matter of much interest, and should the forms on the two sides of the Atlantic be shown to be generically identical, Prof. Seeley's name will have the priority. As it is the propriety of separating these fragments of snouts from *Ornithocheirus* is somewhat doubtful.

DERMODACTYLUS (Marsh, 1881). Prof. Marsh, in the year 1878,† made known the occurrence of a Pterodactyl in the Jurassic Beds of Wyoming, naming it *Pterodactylus montanus*, but afterwards gave it the new generic title of *Dermodactylus*.* The remains of this form which have been found are too fragmentary to give any very definite characters, but it seems that the walls of the bones are thicker than is usual in Pterodactyls: the scapula and coracoid do not appear to have been ankylosed: the vertebræ are procœlous; and the teeth are elongated and rounder than in most Pterodactyls. Prof. Marsh says: "The genus represented by these remains appears to be distinct from *Pterodactylus*, and may be termed *Dermodactylus*. The only known species will hence be *Dermodactylus montanus*." This is the only Pterodactyl known in the Jurassic Rocks of America.

---

* 'Ann. Mag. Nat. Hist,' Ser. iv, Vol. vii, p. 35, *note*.

† 'Amer. Journ. Sci.,' Ser. iii, Vol. xvi, p. 233.

PTERANODON (Marsh, 1876). (Figs. 5 and 13.) The first notice of the occurrence of Pterodactyls in America was made by Prof. Marsh in 1871,† when he called attention to some large bones from the Cretaceous Rocks of Kansas, which he named *Pterodactylus Oweni*, but as this specific name had already been used for a Pterodactyl by Prof. Seeley it was changed in 1872‡ to *P. occidentalis*. Several species from the same horizon have since been described by the same author, and in 1876§ he established the genus *Pteranodon* for their reception. Prof. Marsh states that the remains of more than 600 individuals have been found, most of them representing gigantic species.‖

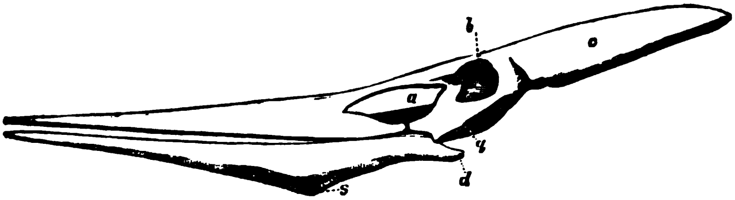


FIG. 13.—*Pteranodon longiceps*. Skull one-twelfth natural size. From the Cretaceous Rocks of Kansas.

The skull is characterized by the complete absence of teeth, and the nasal and ant-orbital fossæ are said to be completely confluent. [N.B.—The ant-orbital fossa is very small in *Ptenodracon* and *Rhamphorhynchus*, and it seems just possible that in *Pteranodon* it has become altogether obliterated.] The occipital region forms an enormous crest, and the jaws appear to have been entirely covered by a bony sheath. The scapula and coracoid are ankylosed, and the distal end of the former has an oblique surface for articulation with the neural spine. The ilia are elongated, the acetabulum is imperforate, the ischia are broad and meeting on the middle line, the tail is short and slender, and the hind limbs are well developed.

---

* Amer. Journ. Sci., Ser. iii, Vol. xxi, p. 342, 1881.

† *Ibid.*, Vol. i, p. 472.

‡ *Ibid.*, Vol. iii, p. 241.

§ *Ibid.*, Vol. xi, p. 507.

‖ *Ibid.*, Vol. xxvii, p. 423, and 'Geol. Mag.,' Dec. 3, Vol. i, p. 345, 1884.

Pteranodon is only known from the Cretaceous Rocks of Kansas.

One species was comparatively small, having a spread of wings of about three feet, while another, *P. ingens*, had a skull four feet long, and must have measured about twenty-five feet across the outspread wings.

NYCTODACTYLUS (Marsh, 1881). Prof. Marsh, in 1876,[*] described as a species of *Pteranodon* some Pterodactyl remains from the Cretaceous Rocks of Kansas under the name of *P. gracilis*, but afterwards,[†] as it showed important differences of structure, proposed for it a new generic title, *Nyctosaurus*. This name, however, was pre-occupied and that of *Nyctodactylus* was substituted for it in 1881.[‡]

Nyctodactylus is closely allied to *Pteranodon*, but is distinguished by having the coracoid distinct from the scapula, and the distal end of the latter has no surface for articulation with the neural spines.

The genus is only represented by one species, and is only known from the Cretaceous Rocks of Kansas. It was of moderate size, its wings extending to about eight or ten feet.

ORNITHOPTERUS (v. Meyer, 1838). Prof. H. von Meyer in 1837[§] noticed some wing bones from the Lithographic Slate which he referred to *Pterodactylus*; but afterwards, on account of the resemblance which the specimen bore to the wing-bones of a bird, he placed it in a new genus and called it *Ornithopterus Lavateri*.[‖] This specimen presented the peculiarity of having only two joints to the wing finger instead of four as appears to be the number in all other *Ornithosauria*.

No additional examples have been found to throw further light upon the structure of this form, and Prof. Huxley says:[¶] "I am much inclined to suspect that the fossil upon which the genus *Ornithopterus* has been founded appertains to a true bird."

---

[*] *Ibid.*, Ser. iii, Vol. xi, p. 508.

[†] *Ibid.*, Vol. xii, p. 479, 1876.

[‡] *Ibid.*, Vol. xxi, p. 342.

[§] 'Neues Jahrb.,' 1837, p. 558.

[‖] 'Neues Jahrb.,' 1838, p. 668.

[¶] 'Anatomy of Vertebrated Animals,' 1871, p. 271.

The genera of *Ornithosauria* above noticed may be thus arranged. The figure placed in a bracket after each name indicates the number of species in the genus.

ORNITHOSAURIA.

PTERANODONTIA.
(Jaws without teeth.)
12. Gen. Pteranodon (6)
13. „ Nyctodactylus (1)

PTEROSAURIA.
(Jaws with teeth.)

Tetrathri.
(4 phalanges to wing finger.)
1. Gen. Pterodactylus (23)
2. „ Cycnorhamphus (1)
3. „ Ptenodracon (1)
4. „ Scaphognathus (2)
5. „ Dimorphodon (1)
6. „ Rhamphorhynchus (4)
7. „ Rhamphocephalus (3)
8. „ Dorygnathus (1)
9. „ Ornithocheirus (40)
10. „ Ornithostoma (1) (? = Pteranodon)
11. „ Dermodactylus (1)

Diarthri.
(2 phalanges to wing finger.)
14. Gen. Ornithopterus (1)

The more intimate knowledge of the structure of the skull and brain in *Pterosauria* which has been obtained by the discovery of *Scaphognathus Purdoni* leads one to inquire whether this knowledge throws any fresh light on the relationship which the Pterodactyls bear to birds and reptiles. Although the general appearance of a Pterodactyl skull is very like that of a bird, it must be borne in mind that the skull of a lizard is also similar to that of a bird, not only in general appearance, but also in many points of structure, and consequently this general resemblance cannot be taken as indicating any closer relationship than exists between birds and lizards. On the other hand, several of the characters which distinguish the skulls of lizards from those of birds are likewise found in the Pterodactyl skull. The form of the back of the cranium and palate, the presence of a bony supra-temporal bar, and of a pre-frontal bone, as well as the small proportionate size of the brain-case, are characters which show the Pterodactyl skull to be much more nearly allied to that of the lizard than to that of the bird. On the other hand, the brain of the Pterodactyl is so very similar to that of *Hesperornis*, in the manner in which the cerebellum comes between the optic lobes and seems to reach the cerebrum, that its affinities seem no less decidedly in the direction of the birds. Pterodactyls, then, hold an intermediate position between birds and lizards and cannot be held to be more nearly related to the one than to the other. Prof. Seeley arrived at very much the same conclusion from the study of less satisfactory materials.

Can we, then, regard the *Pterosauria* as genetically intermediate between birds and reptiles? Is it possible that birds have descended from reptiles through the Pterodactyls? This does not seem possible; but the facts seem rather to point to *Aves*, *Pterosauria*, and *Reptilia* having been derived from some common ancestral type.

It is a striking fact that in the endeavour to trace the origin of the great groups of *Vertebrata* the possible period of their first appearance becomes, with every new piece of evidence, pushed further back in time. Forms which seem to be direct ancestors of others, upon closer examination seem rather to point to a pre-existing common ancestor for both, and thus their probable origin is made more remote. Reptiles closely resembling the crocodiles (*Stagonolepis*), and lizards (*Hyperodapedon* and *Telerpeton*) of the present day were living in Triassic times, and the *Pterosauria* have been traced back to the same period; it is therefore to the Palæozoic Rocks we must look for their origin.

The earliest known bird, *Archæopteryx*, is of Upper Jurassic age; but if, as seems probable, birds, pterodactyls, and reptiles were derived from a common ancestor, then it is to the Palæozoic Rocks we are again led in our search for the origin of birds.

Prof. Marsh, in his work on the 'Odontornithes,'* says: "For the primal forms of the bird-type we must evidently look to the Palæozoic; and in the rich land fauna of our American Permian we may yet hope to find the remains of both birds and mammals."

Although the remains of mammals in Jurassic Rocks are very few, yet they have been traced as far back as the Trias (*Microlestes*); and it is therefore, as Prof. Huxley has said,† in the later Palæozoic Rocks that we may expect to find the remains of the primitive mammalian stock, the *Hypotheria*, a possible type with more sauropsidan affinities than the lowly *Ornithorhynchus*.

If we now turn for a little to the work of biologists among recent animals, in this same investigation, we find their conclusions pointing very much in the same direction.

---

* 'U.S. Geol. Expl. of the Fortieth Parallel,' p. 188, 1880.

† 'Proc. Zool. Soc.,' 1880, p. 658.

Prof. W. K. Parker's developmental researches have led him to conclude that the origin of *Mammalia* must be sought in the *Amphibia* rather than in any higher type of vertebrate creature; indeed, many of his illustrations, used for comparison with early mammalian embryos, are taken from the still lower group of the fishes, and he says* "If I am asked why I dive so far down for my illustrations instead of being satisfied with what reptiles and birds would show me, my answer is that those are often of no use for comparison, for they are as thoroughly specialized for their own mode of life as the Mammalia generally, and are as completely, and often more completely, transformed from the original archaic type or types."

With regard to the root-stock from which the birds have descended, Prof. Parker has said in a paper recently read before the Royal Society† regarding certain vestigial structures in the bird's skull, "They are sufficient, I think, to satisfy any reasonable person that Birds arose, by secular transformation, either from the lowest and most ancient of the true Reptiles, or equally with Reptiles from archaic Amphibia, low in structure, but full of potential excellence, and ready, *pro re natâ*, to become Reptile, Bird, or even Mammal, as the case might be."

We have seen that mammals, reptiles, pterosaurians, and probably birds, were distinct types of vertebrate life at the beginning of the Mesozoic epoch, and that their origin from lower forms, or their common ancestors, must be sought not later than the end of the Palæozoic epoch, that is not later than the Permian or Carboniferous period. And further, it is highly probable that these ancestors will be found among the *Amphibia;* in the very group of animals, that is, which we know were exceedingly abundant in later Palæozoic times, and had already become differentiated into many and varied forms, resembling salamanders, crocodiles, and snakes.

Does not this, then, strengthen the conviction that each of these groups—mammals, birds, pterosaurians, and reptiles—is derived from a separate amphibian ancestor, and that the similarities and differences traceable between these groups at the present day are the modified expression of the relations existing between the Palæozoic *Amphibia.*

---

* 'Phil. Trans.,' 1885, p. 274.

† 'Proc. Roy. Soc.,' Vol. 43, p. 402.

But if these deductions be correct, we seem just as far off as ever from the common ancestral type, for the question now arises, whence came these Palæozoic *Amphibia?* Are the various Carboniferous forms as closely related as we, by our nomenclature and classification, seem to make them? Were they really a group derived from some common amphibian ancestor?

Having pushed the higher groups so far back, and finding them still distinct, and not terminating, as we expected, in a common primitive type, may it not be that when these Palæozoic so-called *Amphibia* are traced further back they also will be found to end, not in one, but in a number of different so-called fish-forms? And then! Where is this all to end?

Such speculations as these may serve a good purpose in pointing out possible directions of research; but when one finds the goal so continually receding one is led to ask whether this is indeed the right road, or whether, in this "worship of ancestors," one has strayed somewhat from the path of truth. It becomes us to take care lest this "primitive type," which, like an *ignis fatuus*, lures us on only to elude our grasp, should lead us away from the solid path of scientific facts to plunge us into the slough of unscientific imagination.

ORDINARY MEETING.

Friday, June 1st, 1888.

F. W. Rudler, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

Mr. W. Greatheed was elected a Member of the Association.

The following paper was then read:—'The Natural History of Gypsum,' by Mr. J. G. Goodchild, F.G.S., F.Z.S.

There were exhibited:—

Specimens of the various forms of Gypsum, exhibited by Mr. Goodchild, in illustration of his paper; and Satin-spar and Gypsum, from Durlstone Bay, Swanage, exhibited by Prof. Boulger, F.L.S., F.G.S.

SOME OBSERVATIONS UPON THE NATURAL HISTORY OF GYPSUM.

By J. G. GOODCHILD, H.M. Geol. Survey, F.G.S., F.Z.S., M.B.O.U.

Amongst the numerous features of geological interest to be examined by the Association on the occasion of the Long Excursion of 1888 are the patches of Rhætic Beds, and their associated strata, the New Red Marls, which remain here and there on both margins of the Bristol Channel. There is much connected with the marls themselves that would repay a long and careful study; but the interest attaching to them is much enhanced by the fact that they form the nidus of several minerals whose complete history is yet by no means well understood. Gypsum is the commonest and the most conspicuous of these; but, common as it is, both here and in other clayey strata occurring nearer the home of the Association, there are many points in connection with its genesis, its mode of occurrence, and even with its physical characters, that are not by any means generally understood. Indeed, some of the problems suggested by a careful study of the subject under notice are of a much more complex nature than a study of our text books would lead us to suppose. The following remarks are intended rather as suggestions for wider investigations than as actual solutions of the problems in question.

In discussing the subject I propose to consider :—(1) what Gypsum is; (2) how it occurs in nature; (3) some of its various modes of formation; (4) and its industrial applications.

It will be convenient to employ the term Gypsum here in a general sense for all the commoner forms of hydrated calcium sulphate ($Ca\ SO_4 + 2H_2O$), whether occurring as minerals or as rocks; and whether visibly crystalline or not. Anhydrous calcium sulphate, or Anhydrite, will be referred to only so far as it is connected with the mineral specially under notice.

The chemical composition of Gypsum varies within small limits; its average percentage composition may be stated as Ca, 33; SO_4, 45; H_2O, 21. The fact that Gypsum contains nearly 50 per cent. of sulphuric acid has set many practical men thinking how they could utilize the vast quantities of that commercially-valuable substance locked up in our extensive deposits of Gypsum.

There is a fortune in store for the chemist who can discover some practical and inexpensive means of accomplishing that result.

The native mineral occurs under many different forms, which may be roughly classified as—(*a*) compact, granular, and finely-crystalline; (*b*) fibrous; and (*c*) the visibly- or largely-crystalline varieties. The purer varieties of (*a*) are often known as Alabaster; of (*b*) as Satin Spar; and of (*c*) as Selenite. To a certain extent it is convenient to recognize these separate varieties; as, in a general way, they may be said each to have originated in a different manner from the other. But, as will be seen presently, there is abundant evidence that each of the three forms may pass into either of the other.

The mineral crystallizes in the Monoclinic or Oblique System. (For details upon this point reference should be made to a special treatise on Mineralogy, such as Naumann's.) Very commonly the crystals are aggregated in more or less complex clusters and combinations, many of them tending to assume stellate forms, which are due to the radial twinning of several conjoined crystals. Very beautiful examples of Selenite are exhibited at the Natural History Museum, and others almost as fine are to be seen in the celebrated Horseshoe Case at the Museum of Practical Geology.

Good crystals of this mineral are so easily obtained that it is surprising that any doubt should exist in regard to the relation of the several faces of the crystals to each other. Yet such is the case, as a comparison of the statements upon that point given in almost any two out of a dozen text-books will show. One or two observations upon this part of the subject may not be altogether out of place here; especially as a correct understanding of the architecture of the Selenite crystal forms a good introduction to the study of the Monoclinic System generally.[*]

If we take any fairly-large simple crystal of Selenite[†] and attempt to cut it in any random direction, it will be at once noticed that there is one plane in particular along which the mineral cleaves with remarkable facility. Along this direction it is very easy to cut off slices of the crystal and to leave the severed faces as bright and as smooth as highly-polished glass. This direction of perfect cleavage follows the plane of the Clinopinacoid (010), which lies parallel to the plane containing the inclined axes of the crystal. In cutting off one of these slices it will probably be noticed that, in one direction, the thin plates being cut off bend almost as easily as lead ; and, like lead, they are flexible, but not elastic. Parallel to the line where the plates bend will be noticed a series of cracks ; and, with a little care, the plate can be broken or cleaved also along any one of these lines. This last forms what is known as the Second cleavage of Selenite. It will be noticed on comparing the planes developed by the First cleavage with those of the Second, that these last are much less perfect, and that they tend to be more or less rough and fibrous. This is evidently due to the powerful interference of the First cleavage, which constantly tends to overmaster any others. The weaker cleavage in this case reminds one of the result when several leaves of a book are torn across the pages. Where the Second cleavage has followed its own direction this is seen to be inclined a trifle over 69 degrees to the face of First cleavage, and is therefore known to coincide with the Positive Hemipyramid. This, it may be remarked, is a face not very common on the crystals themselves. A Third cleavage, still less perfect than the Second, is nearly always present, and is seen to cut the clinopinacoid faces in such a direction as to form an angle of nearly 68° with the corresponding line of the Second cleavage. Along this cleavage it will be noticed that the thin plates snap instead of bending, as they do along the Second. The plane of fracture, where not interfered with by the Clinopinacoid, is at right angles to that face, and it therefore represents the Orthopinacoid (100). These three cleavages, which can be readily made out in every crystal, enable us at once to determine the crystallographic position of any other faces that may be present. One other feature may be noticed before leaving this. In the commonest form of simple crystals of Selenite the side of the crystal representing the Orthopinacoid presents a pair of faces inclined to each other at a variable number of degrees, and always more or less striated or fibrous. These are often regarded as the faces of the Unit Prism, and such in the main they are. But if we turn these faces about under a strong light it becomes evident that the light is reflected from three, or even from four, quite distinct planes ; and that, therefore, these striations represent oscillating combinations of as many sets of faces. These faces are $\infty \not{P} \infty$, ∞P_2, ∞P, and $\infty P \infty$, and the measurement of the angles of the resulting compound faces will vary according to the relative predominance of one or other of its components. The remaining two pairs of faces, which are usually very rough, and more or less irregular through the interference of the First cleavage, are, in the main, those of the Negative Hemipyramid.

---

[*] I am indebted to Mr. Rudler for information upon some of these points.

[†] This usual form is enclosed by four faces of the form (110) and four of (111), forming together what has been called an octahedral scalenohedron, with the two faces of (010), the clinopinacoid. These two faces have a lustre rather pearly than vitreous. Phillips's 'Mineralogy,' ed. Brooke and Miller, p. 536; Rutley, 'Mineralogy,' p. 69; 'Rock-forming Minerals' (1888), p. 220; Gurney, 'Crystallography,' p. 48.—[ED.]

Good examples of simple crystals are common in the Oxford Clay of Shotover Hill.* Very perfect small crystals, showing hemidomes and other faces not very commonly developed in this mineral, occur in the Woolwich Beds at Charlton. One of these I presented to the Museum of Practical Geology two or three years ago, where I hope one day to see it exhibited. The most perfect and clearest crystals come from Bex, in Switzerland. The best examples of the curious arrow-headed forms come from Monmartre.

The hardness of Gypsum is between 1·5 and 2, varying slightly in different specimens. It is also slightly different on the different crystalline faces of the same specimen, being hardest on the hemidomes and softest on the faces of the clinopinacoid, where it can easily be scratched by a finger nail of average hardness. Anhydrite is just a trifle too hard to be scratched in that way, so that the one mineral can easily be known from the other by this test. The specific gravity varies slightly also, it being between 2·28 and 2·33; or, roughly, Gypsum may be said to be about two-and-a-quarter times heavier than water. About fifteen-and-a-half cubic feet of it go to the ton; and a cubic foot of the mineral weighs about a hundred and forty-four pounds. Sulphate of lime exists in sea-water in the proportion of about three and a half pounds to the ton. It forms 90 per cent. of the encrustation of marine boilers.† At a temperature of 32° F. it is soluble to the extent of 0·205 parts, and at 210° F. to the extent of 0·217 parts in 100 parts of pure water. In water containing organic matter its solubility is much increased. Mainly from that reason it is present in variable quantities in all river-waters, and its presence is one of the principal causes of the "permanent" hardness of water. Sulphate of lime precipitated from solution under a pressure of ten atmospheres falls as Anhydrite.

---

* When this paper was read a gentleman present stated that similar forms had lately been found commonly in the London Clay of the North of London.

† C. Tookey, 'Report of Commission on Boiler Explosions.'

Of the three principal forms of Gypsum already noticed, the large crystalline and transparent variety, or Selenite, occurs very commonly, as scattered crystals, throughout most of such argillaceous deposits as are still left in the condition of clay. (Under any changes affecting this kind of rock Gypsum seems to be usually one of the first of its constituents to disappear.) The fibrous form of Gypsum is, almost invariably, confined to veins traversing gypsiferous strata.* The fibres tend to be perpendicular to the walls of the vein; but they are frequently more or less bent, as if from differential movements of the matrix. Some of its purer varieties are known as Satin Spar, and are deservedly in request for ornamental purposes. The massive, granular, cryptocrystalline, or compact varieties seem to be confined almost exclusively to the more extensive aggregations or stratiform deposits of this mineral. Each of the three varieties may commonly be seen in intimate association with either of the others, and associated in such a manner as to suggest that passages from the one form to the other may exist.

Gypsum has been met with here or there over nearly every part of the earth's surface; and it is found here on one geological horizon, there on another, from the Older Palæozoic rocks down to strata in process of formation at the present day. It is, therefore, clear that, in whichever of the many possible ways any particular deposit may have originated, the conditions necessary for its formation have been only to a certain extent exceptional, and are probably represented in many parts at the present day.

Stratiform Gypsum (as distinguished from Selenite) occurs but rarely amongst rocks of easy permeability; and even then only under very exceptional conditions. Why this should be the case it is not at first easy to discover. Its most common nidus is in argillaceous deposits, and in such rocks its origin is not usually very difficult to trace. The evidence generally seems conclusive that it is wholly, or in great part, a contemporaneous formation, due to exceptional physical conditions, which are well understood. In other cases it is clearly due to the partial replacement, or to the alteration, of some other rock whose original composition was different. It may, again, owe its deposition to the action of vitriolescent sulphides upon dissolved calcareous matter once disseminated throughout the rock, which is generally the history of Selenite. Or, lastly, it may have arisen through a kind of concretionary action, whereby sulphate of lime, contemporaneously deposited in a diffused state through a higher mass of strata, has been drained out of these and eventually collected below. In this case it has behaved in much the same manner as the colloid silica of organic origin, which was once diffused throughout the Chalk, and is now tending in a dissolved state to lower levels, there to aggregate as flint.

---

* Mr. Boulger states that he has, in one instance, seen a true bed of fibrous gypsum, in the Purbeck series, at Swanage.

Modifications and combinations of all these causes have clearly been at work, and all of them, and may be others as well, will have to be taken into account in dealing with so complex a question as the origins of the various deposits of Gypsum.

Taking the simpler cases first, where stratiform deposits of Gypsum are mainly contemporaneous with the enclosing rock, a study of the associated phenomena, presented by a large number of cases, at once suggests to the observer that he is dealing with rocks that represent conditions of deposit quite unlike those of a normal formation of marine origin. To begin with the most marked, no one can fail to be struck with the very general association of deposits of Gypsum with variegated strata, such, for example, as the spotted, variegated, and mottled beds of the New Red. This association is traceable through rocks of all ages, occurring in all parts of the world. Even the exceptions to this rule are more apparent than real. Then, again, there are abundant and unequivocal indications of shallow-water conditions, which seem to have prevailed throughout nearly the whole period of deposit. This evidence, it should be observed, does not rest upon such untrustworthy data as those afforded by ripple-marks (which it is now known may be formed at any depth soever where there is a to-and-fro motion of the water), but is based upon the occurrence of desiccation marks, foot-prints of air-breathers, pseudomorphs of rock-salt, and by other evidence as unequivocal in character. Then, again, Gypsum is usually associated with other chemical deposits different from any that occur in connection with normal marine strata. Amongst these chemical deposits one may regard as the regular associates of Gypsum such substances as anhydrite, magnesian limestones, as well as limestones dolomitized by magnesian infiltrations, rock salt, iron salts in a diffused state, but locally concentrated, manganese peroxides, silica in rather unusual modes of occurrence; and, less frequently, sulphur, celestine, and barytes. Organic matter in any form is either rare as an associate of stratiform deposits of Gypsum, or is conspicuous by its absence.

Then, again, there is frequently evidence of unusual modes of transportal of the materials composing the rocks, if these happen to be coarsely fragmental. Lastly, the proximity of volcanoes, or some evidence of volcanic action, is much too frequent a concomitant to be merely accidental.

In regard to the geological distribution of Gypsum a few words will suffice. One of the oldest deposits of Gypsum known is said to be that of the Salt Range of the Punjaub, where it occurs with rock salt in strata regarded as of pre-Silurian age.* In New York it occurs in the (Silurian) Salina formation in connection with red marls. In the " Devonian " Rocks of Russia Gypsum is found as usual associated with red and green marls, and with beds of dolomite. It is found in the Calciferous Sandstone series of the south of Scotland, there in association with coloured clays, with abundant evidence of shallow-water conditions, and with rocks of volcanic origin. Its occurrence in the Red Rocks of Britain and elsewhere is known to the veriest tyro in geology; and from these rocks upwards through various newer members of the Neozoic series—Jurassic, Neocomian, Cretaceous, and Tertiary—it is represented as a contemporaneous deposit, in one locality or another, on almost every horizon known to the geologist. In the majority of these occurrences the nature of its surroundings is, in all essential particulars, the same as that noticed in the generalized description given above.

Confining our attention on the present occasion to our principal British deposits of Gypsum, we find that these occur on two widely separated geological horizons. The more recent of these is in the newer Jurassic rocks, and is represented by the very exceptional deposit now being worked at Netherfield, near Battle. The older, and much-better known horizons, occur on two platforms in the

---

* Wynne, 'Mem. Geol. Survey of India,' Vol. xi, p. 189. The origin of Gypsum is discussed at more or less length by Mallet ('Mem. Geol. Survey India,' Vol. v, p. 153), by Captain Herbert ('Asiatic Researches,' xviii, p. 216), by Cautley ('Journ. Asiatic Soc. Bengal,' i, p. 289), by Everest (*ibid.*, p. 450), etc.

New Red (employing that term in its older sense to embrace all the red rocks between the base of the Rhætics and the top of the Carboniferous ; that is to say, for the true basement beds of the Neozoic Rocks). As these New Red deposits of Gypsum present characters that may be fairly regarded as typical, their mode of occurrence may here be considered in somewhat fuller detail than that of the Netherfield rocks, whose anomalous character can be more conveniently discussed at a later stage.

Regarding our British Red Rocks in a broad and general way, one sees that they consist of the following groups, which are here stated in descending order, and without any regard to conventionalities in the matter of names, and the like :—

c. Rhætic Beds.
b. New Red Rocks.
  (5). An upper group of red marls, more or less variegated, and locally containing beds of flagstone ; with, also, lenticular deposits of salt, Gypsum, and, near the base, thin bands of magnesian limestone.
  (4). A variable group of sandstones and pebble beds, with a prevailing tint of red, and more or less variegated throughout.
  (3). A lower group of red marls, etc., mottled like the upper group ; and also, like them, containing variable beds of flagstone, of salt, of Gypsum, and, near the base—
  (2). Lenticular beds of magnesian limestone, with some thin marls and sandstones. (As chemical precipitates the magnesian limestones might be expected to be very local in their occurrence ; and their absence at any given spot, below the New Red Rocks, is nearly always to be attributed rather to non-deposition than to denudation.)
  (1). A variable series of red sandstones, breccias, and conglomerates, which are locally interbedded with volcanic rocks. All the beds are more or less deeply imbued with red oxides of iron, and with them are associated also manganese oxides, magnesian salts, and more or less introduced silica in the form of secondary quartz.
a. Various older rocks unconformable to the beds above.

Where the complete series is present, as it is, for example, near Penrith, near Stockport, near Dawlish, and in the West Midlands, the aggregate thickness may amount to four or five thousand feet, or even to more than that. But, owing partly to large inequalities of the old floor, and partly also to important irregularities of subsidence, the lowest members of the series are present in only a few places. On the other hand, as in the country around Bristol, the salient inequalities of the surface appear to have been maintained (probably in part through undulatory movements of the earth's crust there) long enough to keep certain areas above the highest zone of deposition of the Red Rocks. In these particular areas, therefore, no Red Rocks were deposited at all.

Between the two extremes of deposition every intermediate phase may be traced, and any one of the five subdivisions may form the local base of the series. But whichever it may happen to be, that basal member is almost certain to exhibit more or less coarsely fragmental characters, and frequently to assume those of breccias whose components largely consist of fragments derived from older rocks near by.

In the present subject the zones we are principally concerned with are the two zones of red marls, respectively denoted by the 5 and the 3 of the section. The foregoing observations will serve to make it clear why group 3 is more commonly absent than group 5, and why this last (the higher of the two) is the widest spread of all the members of the Red Rocks. These two zones form the chief sources of the Gypsum obtained in Britain. In lithological character both may be described as piles of thin beds of red clay, with a more or less evident lamination throughout, so that they tend to pass into shales. In the sense conveyed by the text-books these rocks have no claim at all to be called "marls," as there is really very little lime in their composition. On the other hand, the term marl is applied over nearly half the kingdom to any rock that readily "merls" or crumbles to bits on exposure to the weather, which is very descriptive of the behaviour of the rocks under notice. The limitation of the term to calcareous clays, although, possibly, it may be convenient, is in one sense an innovation, and not altogether a justifiable one either. Both of these marls, study them where one may, are remarkably alike in character, so that a description applicable to one will equally well suit the other. They are always of some hue of red—dull Venetian Red, Copper Red, Brick Red, or something of that kind, with here and there pale grey-green, sometimes with pale saffron-coloured, or whitey-brown bands, and with discoidal spots of the same pale hues as the bands. Occasionally the spotting and variegation take a more irregular form, and the beds may be described as mottled or dappled. It is curious to note how the discolorations extend through the rocks quite regardless of bedding planes.* I have before me as I write some specimens of conglomerate of this age, wherein certain pebbles are bright red on one half and pale green on the other; the change of colour extending right across the bedding of the rock. Here and there a few bands assume arenaceous characters, which may even develop into flags, or into sandstones; but everywhere the argillaceous character is the prevailing one. The clays seem to have been deposited in comparatively quiet, undisturbed water, which seems never to have varied much from shallow conditions, even throughout the whole of a thick mass. The greatest proved thickness of any of these marls in the kingdom is about a thousand feet; generally it is less than that. The statement is commonly made that the New Red Marl of the Welsh borders is 3,000 feet in thickness; but no one seems to know either where, or how, that great thickness was made out. The lower marls (3) are usually much thinner. Fossils are very rare in both, perhaps because the physical conditions that prevailed during the formation of the marls were unsuitable to life, perhaps because chemical changes affecting the rocks since their formation have removed any traces that may at one time have existed.

Coming now to the Gypsum itself, we find, on an examination of almost any large exposure of these marls, traces, at least, of small groups of crystals of selenite, often in stellate combinations, along the bedding planes of the marls, or otherwise dispersed throughout the rock itself. Locally, these stellate groups may be observed to be congregated in large numbers, so as to interlace with each other among the clays, or they may even, locally, occur in such abundance along certain planes as almost to form thin beds. More commonly they will be found disseminated through the mass of the clay, occurring, perhaps, in tolerable abundance along particular zones, and being comparatively rare along others; so that one may regard the rocks in such cases as mixtures, in variable proportion, of clay and diffused crystals of selenite. Passing beyond this phase of development of the gypsiferous clays, we begin to find the cracks and joints and other divisional planes of the clays traversed by thin veins of pure Gypsum, whose white colour very commonly presents a very marked contrast with the reds, greens, and greys, of the enclosing strata. This vein-gypsum is nearly always fibrous, with the fibres normally arranged perpendicularly to the walls of the vein, except where local movements have dragged them out of that position. Examination of a wider area shows that these veins ramify in various directions, and that, as a rule, they become both more numerous and more fully developed in regard to size as they are traced downwards. With this increase in size of the vein-gypsum, and with the further development of the selenitic matter occurring in the clays, commences a more or less decided tendency towards a development of nodular masses in the clays. In these every gradation of development can be traced, from the periphery of the nodule, where laminar masses of selenite are interlaced with clay, through more compact and purer portions, into regular granular gypsum, such as characterizes the stratiform deposits. It is perfectly clear in such cases that these nodular masses of Gypsum (and many of these are of large dimensions) represent little else than local concentrations of selenitic matter, which at higher levels is simply represented by dispersed crystals of small size scattered throughout the clays. The same observation applies not only to the nodular masses referred to, but also to some of the thinner beds. Indeed, in the case of the Netherfield gypsiferous beds this point comes out very clearly, even in an examination of hand specimens. From this phase of development it is often easy to trace further gradations, up to the point where nodular masses of various dimensions consist entirely of mixtures in variable proportions of selenite, satin spar, and granular gypsum—the clay at that point having been, it would seem, entirely extruded by the growth of the nodule. I have seen many such cases, especially in Staffordshire, and in both Westmorland and Cumberland, where large nodular masses of Gypsum have steadily grown *in situ*, and have clearly extruded the clay whose position they now occupy. In such cases the original bedding of the marls can be distinctly traced through the nodules themselves, just as in the case of the nodular masses of ironstone, or of calcareous matter, concreted in many of our Carboniferous Sandstones, or as the bedding of the Chalk can be traced through flint, or of the Carboniferous Limestone through chert, or, again, of the same limestone through the pockets of hæmatite occurring in it in Cumberland and elsewhere. In each and all of these cases, gypsum, flint, hæmatite, it is clearly a case of replacement, only that in the case of the Gypsum molecular change has played a less important part, and mechanical forces have been at work equally with the chemical.

---

* For fuller information upon this point consult Mr. Geo. Maw's paper, 'Quart. Journ. Geol. Soc.,' xxiv, p. 351.

Extensive deposits of Gypsum occur almost exclusively in the form of irregular, concretionary, nodular masses; which alternately swell out into masses of pure Gypsum, or pass horizontally into selenitic clays, and that, too, within very short distances. There is nothing inconsistent with this in the fact that on the larger scale such deposits of Gypsum should be fairly persistent, any more than there is in the fact that certain zones of flint, for example, are constant over a hundred or more square miles, although the individual flints composing that bed may be discontinuous from their neighbours at every few inches. Large deposits of Gypsum are more or less of the nature just described, and it is far from unlikely that, when the subject comes to be more fully looked into, this mode of occurrence will be found to be much commoner than has been supposed.

In association with the nodular Gypsum just described, one occasionally meets with deposits of a much more persistent character. These differ from the nodular deposits only in regard to their horizontal extension. Some of the best examples of these occur on various horizons close above, or close below, the Magnesian Limestone in the North of England. These have long been worked in open quarries in the lower parts of the basin of the Eden, between Appleby and Carlisle. A careful examination of these in the field teaches us that much the same mode of occurrence as that just described characterizes these deposits also. But, on the other hand, their stratiform features are often strongly marked, and it is difficult to believe that in these cases we are not dealing with a veritable stratum contemporaneous with the beds amongst which it now occurs. Still, there is present the same evidence of passage into nodular Gypsum, which can be traced into fibrous Gypsum, or into selenitic marls; and it is quite certain in many cases that the lamination seen in the Gypsum can be traced into the marls, as in the other cases noted. And there is, again, abundant evidence of irregular upgrowth of the surface, as if the same kind of action that has been at work concreting the nodules had in this case simply united, or added on, Gypsum that had been drained out of the clays above, to a pre-existing sheet or bed occurring below. My own impression, gathered from a long study of these facts, is that lenticular deposits of Gypsum were formed contemporaneously in some cases, and that these have since been added to, irregularly thickened, perhaps locally united, by Gypseous matter originally diffused through the strata above, which has been slowly dissolved and has drained to lower levels, where it has concreted around older aggregations below. This view will enable us to account satisfactorily for such of the marked irregularities of the upper surface of the Gypsum as are not referable to the dissolving action of surface waters charged with organic matter, a point to be noticed more fully presently. It will also serve to explain the strange contortions so commonly seen in clays overlying Gypsum in deposits of all ages all the world over. The Westmorland and Cumberland Gypseous deposits appear to be, to a certain extent, what may be termed complementary deposits, as they set in where the Magnesian Limestone is dying out, and thus appear to represent merely a different phase of the conditions that led to the precipitation of the Magnesian Limestone. That selenite, at least, was formed contemporaneously with this rock is shown by the fact that moulds of selenite crystals occur commonly in the midst of some of the bands of the limestone itself.

A thickness of between 1,500 and 2,000 feet of red and mottled, and, locally, conglomeratic, sandstones (4) overlies the Lower Gypseous Shales in Cumberland and Westmorland. It is full of evidence of shallow-water conditions, from bottom to top. No traces of Gypsum occur in this. Above this group of sandstones comes, in Cumberland, as elsewhere, a higher group of red marls, (5) of the section (p. 432). These marls are unquestionably the equivalents of the so-called "Keuper" Marls of other parts of the kingdom. It is in these Keuper Marls, and not in the Lower Marls (3) just noticed, that the chief deposits of Gypsum elsewhere are located. Oddly enough, in Cumberland such deposits do not appear to be present. There are, it is true, Gypseous bands in these beds at Stanwix, near Carlisle, as there are pseudomorphs of Rock Salt, and as there are also thin bands of magnesian limestone; but the great saliferous and gypseous deposits that characterize these marls in Cheshire, etc., have, so far, not yet been detected there. It will be seen by this that there are two perfectly distinct gypsiferous horizons in the New Red, one of them being on, or near, the horizon of the Magnesian Limestone, as in Cumberland, and Westmorland, and Durham ; the other, and better known, in the Keuper Marls, as in Cheshire, Staffordshire, Warwickshire, Somersetshire, etc.

In regard to the phenomena associated with the Gypsum in the Edenside (Cumberland and Westmorland) localities, it is evident that there is a marked connection between Gypseous deposits and clayey strata, which are all variegated more or less. With it occurs Magnesian Limestone, sometimes even interbedded with it. Patches and nests of oxides of manganese are present, and traces of rock salt have been met with. Lastly—and these are points of considerable importance—in the beds below the New Red there is abundant evidence of the downward percolation of ferruginous matter. This at present exists either in a diffused state, staining the rocks, or else, locally, in a concentrated form as hæmatite, where the conditions were such as to favour the dissolution of calcareous matter and to effect the replacement of this dissolved calcareous matter by one or more of the compounds of iron. Then, again, the calcareous beds below the New Red, or existing as breccias in it, have been extensively acted upon by magnesian solutions, which have converted the limestone, etc., into dolomites. Finally, the sandstones in the lower part of the New Red are often deficient in both felspar and mica ; but they have received, evidently, a superaddition of free silica, which, commonly, has been deposited in the form of secondary quartz upon the grains of sand.* The last observation applies also to certain of the older sandstones that have been exposed to the same set of infiltrations. What is true of these Edenside deposits in this connection is true also of many similar deposits in other places, so that one cannot help thinking that the associations here referred to are something more than accidental ; and that these varied phenomena are, perhaps, little else than so many different results of one and the same set of causes as those that gave rise to the deposits of Gypsum.

The question then rises, What were those causes? The question is much more easily asked than answered, for it is certain that very few substances occurring in nature have been produced in so great a variety of ways as Gypsum may have been.

---

* Doubly-terminated crystals of quartz occur within deposits of Gypsum in many localities, especially in India.

Taking first the case of ordinary Selenite, such as occurs in the London Clay. At first sight, judging by the almost self-evident facts in this case, nothing could seem to be clearer than that we are here dealing with an instance where the decomposition of iron sulphide (?marcasite), so common in the London Clay, has given rise to sulphuric acid, which has combined with some of the calcareous matter so abundantly diffused through the same deposit, and has formed selenite in consequence. It cannot be otherwise in this case. So, too, with other clays, vitriolescent sulphides furnish the one ingredient required and shells the other, and selenite is the result. The process in both cases is partly aided by the presence of decaying vegetable matter, as it is well known that the faculty that plants possess of decomposing carbonic compounds when they are alive is exchanged for that of decomposing sulphur compounds when they are dead. But there is plenty of iron sulphide in its most readily decomposed form, marcasite, in the Chalk, where, certainly, calcareous matterais not wanting. Yet who has seen much, or any, Gypsum in the Chalk ? Why not ? Some factor is wanting, and we have yet to discover what that factor is. Possibly the formation of Gypsum is favoured by a low rate of permeability of the matrix, and is not possible where a comparatively rapid circulation obtains. Then, again, iron sulphide in some form or another is of common occurrence in the mineral veins traversing the Carboniferous Limestone of the North of England, and in these veins one would have thought that the conditions necessary for the formation of selenite were present in the highest perfection. Yet have I only once or twice met with selenite in connection with them during a pretty extensive practical experience in their midst.

Mr. A. B. Dick suggested to me some time since that the sulphuric acid liberated in some of these cases may immediately enter into fresh combinations with the base, and may, therefore, practically not be liberated at all. He has also pointed out to me that certain varieties of both pyrite and marcasite resist decomposition for very much longer periods than other varieties of each of these species ; and that, too, without any apparent reason for the difference of behaviour. As an illustration, he referred to the pyrites remaining apparently unchanged in some specimens of Welsh slate, which are known to have been exposed to the action of the weather for fifty years or more. Evidently we have yet much to learn on many of these points.

Passing now to the consideration of other possible modes of formation, I need not do more than refer to the formation of Gypsum from anhydrite, as the discussion of that merely shifts the difficulty to another place.

The formation of Gypsum by the action of sulphurated waters, or of sulphuretted hydrogen (as in the case of Solfataras) upon limestone, is a well known phenomenon; it will be found described in detail in Bischoff's 'Chemical Geology.' There does not appear to be any case of this kind yet clearly made out in Britain.

In some few other cases small masses of gypsum may be due to direct deposit from thermal springs. Some of these may represent gypsum derived from sea-water which has had some of the water boiled out of it by volcanic action.

Another explanation of the origin of both gypsum and rock salt is given in Dr. Sterry Hunt's 'Chemical and Geological Essays,' and is ably advocated by Sir Andrew Ramsay. According to this view many of these deposits are due to concentration, by evaporation, of the river-water flowing into natural basins without any outlets, in which basins the soluble matters carried down by the river gradually accumulate, are each eventually thrown down, as soon as their respective degrees of saturation are passed. Deposits of this nature are undoubtedly taking place on many parts of the earth's surface at the present day. One of the best descriptions of lakes of this nature is given in Mr. Russell's 'Lake Lahontan,' from Monograph XI. of the 'United States Geological Survey.' Mr. Russell describes these "playa lakes" in much detail.*

Another explanation that has been given is based upon the well-known fact that, on the evaporation of a solution containing bicarbonate of lime and sulphate of magnesia, a double decomposition takes place, with the result that both gypsum and bicarbonate of magnesia are precipitated. The formation of magnesian limestone by such causes must, almost of necessity, be of a very local character; and it is not difficult to understand how vast, reef-like masses of dolomite may be thus formed, without the direct intervention of organic agencies at all. Some of the "reefs" of dolomite in central Europe may be of this nature, and thus be not in any way connected either with corals or with any other organized beings. The discontinuity and the abrupt termination of such deposits are almost necessary consequences of their particular mode of origin. The lesser variations in thickness of our own Magnesian Limestone are more probably attributable to the same original cause, rather than to any denudation during "Bunter" times.

---

* See also Lartet, 'Bull. Geol. Soc. Fr.,' 2nd, xxii, p. 450.

Results very similar to those that follow the concentration by evaporation of the waters of closed areas of inland drainage, obtain when an arm of the sea is isolated and exposed to the same conditions. Such cases as these last must have occurred again and again in past times; and doubtless there yet exist deposits of gypsum that have originated in that way. But then, on the other hand, it has to be borne in mind that the relative proportion of dolomite, gypsum, rock salt, etc., as these usually occur in gypsiferous deposits, is far from being the same as we should expect to find in strata originating in the manner under notice. A consideration of the main points in the following extract may serve to make this more clear:—

In the 'Popular Science Monthly' for October, 1882, Mr. Dieulafait describes the succession of chemical precipitates that are formed on the evaporation of sea-water:—

"First a very weak precipitation occurs of carbonate of lime with a trace of strontium, and of hydrated sesquioxide of iron mingled with a slight proportion of manganese. The water then continues to evaporate, but remains perfectly limpid, without forming any other deposit than the one I have mentioned, until it has lost 80 per cent. of its original volume. It then begins to leave an abundant precipitate of perfectly crystallized sulphate of lime with two equivalents of water, or gypsum, identical in geometrical form and chemical composition with that of the gypsum beds. This deposit continues until the water has lost 8 per cent. more of its original volume; then all precipitation ceases until 2 per cent. more of the original quantity has evaporated away. Then a new deposit begins, not of gypsum, but of chloride of sodium, or sea salt. . . . The deposition of pure or commercial salt continues until the volume of the water has again been reduced by one-half, when a precipitation of sulphate of magnesia begins to take place with it." The writer then goes on to point out that a body of sea-water evaporated naturally will leave a succession of chemical of the weather for fifty years or more. Evidently we have yet much to learn on many of these points.

Passing now to the consideration of other possible modes of formation, I need not do more than refer to the formation of Gypsum from anhydrite, as the discussion of that merely shifts the difficulty to another place.

The formation of Gypsum by the action of sulphurated waters, or of sulphuretted hydrogen (as in the case of Solfataras) upon limestone, is a well known phenomenon; it will be found described in detail in Bischoff's 'Chemical Geology.' There does not appear to be any case of this kind yet clearly made out in Britain.

In some few other cases small masses of gypsum may be due to direct deposit from thermal springs. Some of these may represent gypsum derived from sea-water which has had some of the water boiled out of it by volcanic action.

Another explanation of the origin of both gypsum and rock salt is given in Dr. Sterry Hunt's 'Chemical and Geological Essays,' and is ably advocated by Sir Andrew Ramsay. According to this view many of these deposits are due to concentration, by evaporation, of the river-water flowing into natural basins without any outlets, in which basins the soluble matters carried down by the river gradually accumulate, are each eventually thrown down, as soon as their respective degrees of saturation are passed. Deposits of this nature are undoubtedly taking place on many parts of the earth's surface at the present day. One of the best descriptions of lakes of this nature is given in Mr. Russell's 'Lake Lahontan,' from Monograph XI. of the 'United States Geological Survey.' Mr. Russell describes these "playa lakes" in much detail.*

Another explanation that has been given is based upon the well-known fact that, on the evaporation of a solution containing bicarbonate of lime and sulphate of magnesia, a double decomposition takes place, with the result that both gypsum and bicarbonate of magnesia are precipitated. The formation of magnesian limestone by such causes must, almost of necessity, be of a very local character; and it is not difficult to understand how vast, reef-like masses of dolomite may be thus formed, without the direct intervention of organic agencies at all. Some of the "reefs" of dolomite in central Europe may be of this nature, and thus be not in any way connected either with corals or with any other organized beings. The discontinuity and the abrupt termination of such deposits are almost necessary consequences of their particular mode of origin. The lesser variations in thickness of our own Magnesian Limestone are more probably attributable to the same original cause, rather than to any denudation during "Bunter" times.

---

* See also Lartet, 'Bull. Geol. Soc. Fr.,' 2nd, xxii, p. 450.

Results very similar to those that follow the concentration by evaporation of the waters of closed areas of inland drainage, obtain when an arm of the sea is isolated and exposed to the same conditions. Such cases as these last must have occurred again and again in past times; and doubtless there yet exist deposits of gypsum that have originated in that way. But then, on the other hand, it has to be borne in mind that the relative proportion of dolomite, gypsum, rock salt, etc., as these usually occur in gypsiferous deposits, is far from being the same as we should expect to find in strata originating in the manner under notice. A consideration of the main points in the following extract may serve to make this more clear:—

In the 'Popular Science Monthly' for October, 1882, Mr. Dieulafait describes the succession of chemical precipitates that are formed on the evaporation of sea-water:—

"First a very weak precipitation occurs of carbonate of lime with a trace of strontium, and of hydrated sesquioxide of iron mingled with a slight proportion of manganese. The water then continues to evaporate, but remains perfectly limpid, without forming any other deposit than the one I have mentioned, until it has lost 80 per cent. of its original volume. It then begins to leave an abundant precipitate of perfectly crystallized sulphate of lime with two equivalents of water, or gypsum, identical in geometrical form and chemical composition with that of the gypsum beds. This deposit continues until the water has lost 8 per cent. more of its original volume; then all precipitation ceases until 2 per cent. more of the original quantity has evaporated away. Then a new deposit begins, not of gypsum, but of chloride of sodium, or sea salt. . . . The deposition of pure or commercial salt continues until the volume of the water has again been reduced by one-half, when a precipitation of sulphate of magnesia begins to take place with it." The writer then goes on to point out that a body of sea-water evaporated naturally will leave a succession of chemical deposits arranged one below the other in the following order:—Sea salt mixed with sulphate of magnesia; pure sea salt; pure gypsum; deposits of carbonate of lime or of dolomite, with sesquioxides of iron, manganese etc. This extract is taken from Russell's 'Lake Lahontan.'

In the case both of isolated areas of sea-water and of closed lakes it is obvious that the conditions necessary to bring about the continuous deposition of a large quantity of any given salt would require that the containing water should be maintained at exactly the same degree of salinity until that quantity had been precipitated. With increased salinity the precipitation of salts of other kinds would ensue; with the salinity diminished precipitation would take another form, might cease entirely, or might give place to sedimentation. It is of course quite possible that the exact balance between the influx of water into closed basins and the subsequent evaporation of that water may now and then have been maintained sufficiently long to admit of the uninterrupted precipitation of such masses of sulphate of lime as occur in our Red Rocks. But all the facts brought to light by a study of the closed lakes of the present day testify to the view that such forms of deposition are very exceptional. Instances are, in fact, unknown. On the other hand the phenomena presented by such cases as have been carefully examined shows that variation in the proportion of rainfall to evaporation, and, therefore, corresponding variations in salinity, have been the rule and not the exception. In all of them the prevailing mode of occurrence of the chemical precipitates is that of thin sheets—varying from a few inches in thickness, to mere films of disconnected spangles—which are interleaved with a succession of sedimentary deposits brought in by freshets.

It is this type, it appears to me, that has prevailed as the initial form of most (perhaps of all) of our British deposits of Gypsum. They seem to represent numerous episodes of higher salinity in the history of the old inland lakes—the normal periods, or those of lower salinity, being represented by the ordinary form of sediment present in those rocks. The sulphate of lime was thus at one time diffused throughout the sedimentary strata, just as siliceous organisms are dispersed throughout the Grey Chalk. Subsequent infiltration has dissolved some of this material and has transported it to lower levels, where it has been concentrated in more or less nodular, or even as stratiform, masses.

According to this view, therefore, the mode of formation of nodular, or of stratiform, Gypsum is analogous to that of flint. Some of the parallels between the two cases have already been pointed out. There is one point, however, where the resemblance ends. Flints, or chert nodules, either occupy pre-existing spaces (such as joints) or else take the place of the calcareous matter by molecular replacement. To a certain extent this may be true of Gypsum also. But in the main the field evidence is in support of the view that the growth of the stratiform Gypsum is due, not to a replacement of its matrix, but to a gradual displacement of the beds around. A slow and steady downward percolation of sulphate of lime, drained in solution from the overlying rocks, is temporarily arrested by some local causes, and begins to accumulate and to extend along any plane that offers the least resistance to its outgrowth. The deposit grows by further additions, extruding a corresponding quantity of the matrix as it does so. In time the whole of the sulphate of lime has drained out of the overlying strata, and the growth of the stratiform mass ceases. In this way, I conceive, most of our Gypseous deposits have arisen. Even the Gypsum in the Ashburnham Beds at Battle may represent so much sulphate of lime, at one time diffused throughout the overlying Wealden strata of lacustrine origin, and eventually collected at a lower level.

Now, one result of the upgrowth of Gypsum in the way described must be that of more or less disturbance of the strata, whose place, according to this view, it has invaded. If a mass of strata of equivalent bulk has been extruded by the Gypsum it is clear that some indications of that extrusion must exist. That, in point of fact, is exactly what we do find. It is hardly possible to examine any good clear section of the strata overlying a thick deposit of Gypsum without being struck with the amount of disturbance these beds have undergone. The fact has been noted again and again, although its significance has been missed. The disturbance has been almost universally attributed to the increase in volume assumed by sulphate of lime in passing from its anhydrous condition, or anhydrite, to its hydrous or commoner form Gypsum. Doubtless this, too, has had its share in the work; but the chief cause is, I believe, the one stated above.

Other disturbances of the strata associated with Gypsum are due, often very largely, to a process the reverse of the last. Gypsum is very readily soluble, especially in water holding organic matter in solution. At the points where deposits of Gypsum come within the reach of percolating water charged with organic matter it is converted into the sulphide and is carried away as such in solution (perhaps to be deposited again at lower levels still). But the immediate result, so far as the Gypsum is concerned, is the formation of great crevasses, caves, and moulins, like those on a glacier. And with this dissolution of the Gypsum ensues more or less down-sinking and other disturbances of the rocks above. Occasionally pot-holes are formed over an area of Gypsum wasting in this way, just as they are formed over chalk under like circumstances.

Returning to the origin of the Gypsum we find several questions remaining to be answered. One of these is:—How came it that during the formation of a mass of gypsiferous strata (often thousands of feet in thickness), shallow water and closed-lake conditions were maintained throughout so long a period of accumulation? It is very doubtful whether the sea itself really ever encroached upon the area where our Red Rocks were forming. And yet there must have been great depression of the surface going on.

Another question, really connected with the last, is—Whence originated all the complex chemical changes that were taking place at this period? How came it, amongst other matters, that so large a quantity of iron salts, of carbonate of magnesia, and of free silica (largely deposited since as secondary quartz) occurred in these rocks? Where is all the mica that one would expect to meet with in the New Red Sandstones, but which is so conspicuous by its absence in many of them? Evidently, complex chemical changes had been set going by some unusual causes.

I have remarked above upon the curious association of these Red Rocks with evidences of volcanic action. Possibly the answer to some of these questions may be:—To the first question, that it is chiefly in the neighbourhood of volcanoes that undulatory changes of level of the earth's crust are taking place. Which is cause and which is effect it is hard to say; but it is near volcanoes that local upheavals and local subsidences occur contemporaneously and side by side. And it is only by means of such partial and undulatory changes of level that any large area of inland drainage can be formed or can be maintained.

Given the proximity of volcanoes the other question can be answered readily enough. Thermal springs and fumaroles will account for a considerable number of chemical changes if their influence extend to closed bodies of water. The decomposition of magnesian and other silicates, and of basic igneous rocks, would furnish the iron salts, the magnesia, and the free silica, concurrently with the formation of the Gypsum. Possibly the volcanoes themselves may have helped in other ways. If they engulph large quantities of sea water, concentrate this as the pressure diminishes, by boiling, and then eject it with other emanations as volcanoes do, we have not to seek far for another agent capable of initiating a far more complex series of chemical changes than we have need to consider here.

In regard to the economical uses of Gypsum, space will not admit of my stating much. A neat summary of that part of the subject is given in Hunt and Rudler's 'Guide to the Museum of Practical Geology.' Further information, also in a compact form, is given in the 'Encyclopædia Brittanica.' Its employment for indoor statuary and carved work is well illustrated in the Museum just named.* As a fixative of ammonia it is coming largely into use for agricultural purposes. Lastly, one of its latest applications is in the manufacture of a fire-proof, quick-setting, and, to a certain extent, weather-resisting cement.

ORDINARY MEETING.

Friday, July 6th, 1888.

F. W. **Rudler**, Esq., F.G.S., Hon. Sec. A.I., President, in the Chair.

The donations to the Library since the previous meeting were announced, and the thanks of the Association accorded to the various donors.

The following gentlemen were elected Members of the Association:—G. W. Butler, B.A.; W. H. Cundell; and P. E. Swinstead.

The following papers were then read:—'On the Rhætics and Lias of Glamorganshire, with reference to the Long Excursion,' by Mr. H. B. **Woodward**, F.G.S.; 'Some account of the district to be visited in the Long Excursion,' by Mr. W. F. **Gwinnell**,

---

* When this paper was read Mr. Rudler referred at some length to its employment also in the "burtonization" of water for brewing purposes.

F.G.S.; 'On the Geology of the Forest of Dean, with reference to the Long Excursion,' by Mr. E. WETHERED, F.G.S., F.C.S.; and 'On the Clays of Bedfordshire, with reference to the Bedford Excursion,' by Mr. A. C. G. CAMERON.

There were exhibited :—

Specimens in illustration of their papers, exhibited by Mr. H. B. WOODWARD and Mr. W. F. GWINNELL; Flint-implement from the Ballast Pit, Bedford, and specimen of Kellaways Rock of Bedfordshire, exhibited by Mr. A. C. G. CAMERON; and Forms of Crystals drawn for the stereoscope (plain and coloured), exhibited by Mr. J. LOVE, F.G.S.

The first three of the above papers will appear in No. 9, the Excursion Number, of the 'Proceedings.'

THE CLAYS OF BEDFORDSHIRE.

BY A. C. G. CAMERON, H.M. Geological Survey.

Great interest undoubtedly centres in the ancient River Gravel at Bedford, containing, as it does, the flint implements that were fashioned and used, probably, by the earliest inhabitants of the land.

Perhaps next in point of interest to the Gravel of Bedford is its Clay. Not that it possesses special features distinct from those of other districts where it is developed; but when we consider that clay land constitutes a third of the whole area of the county, and that, owing to the scarcity of good building-stone, we are indebted to the clay for the bricks so extensively used as building material, an interest attends it rendering it well worthy of remark amongst the other physical phenomena recorded from the district.

According to the Agricultural Returns of the Board of Trade, 1887, the total area of Bedfordshire is 295,509 acres, of which a third is clay; not, however, one homogeneous clay, but in several areas, each of which has its own clay formation. These clays, six in number, are in ascending order—Great Oolite Clay, Oxford Clay, Ampthill Clay (referred to the Kimeridge Clay), Gault Clay, Boulder Clay, and Alluvial Clay. The areas of the first and last being inconsiderable they may be at present disregarded. Gault has no place in the immediate neighbourhood of Bedford, and will, therefore, be but briefly described. A short note, too, will suffice for the Ampthill Clay, albeit there are some interesting points about it. Those that remain, the Oxford Clay and the Boulder Clay, occupy together by far the larger portion of the clay region. It is from the former that our bricks are prepared, while some of the most fertile tracts in the country are situated on the latter.

The Bedfordshire Gault is a bluish and grey calcareous clay, fossiliferous, and with whitey-brown phosphatic nodules, sometimes coprolitic. It is exposed in the land south of Leighton Buzzard, where it gives a whitish tinge to the soil newly turned up by the plough, partly due to the downwash from the adjacent range of chalk hills. The Gault country is flatter than that of the Oxford Clay, and even where drained is sometimes moist and marshy, and is mainly kept in pasture. It forms a part of that immense, well-wooded plain that spreads westwards from the foot of the Chiltern Hills, and includes part of the Vale of Aylesbury. The true character of its soil is best observed away from the influence of the Chalk, when it presents a surface of cold, retentive clay, requiring large capital, skill, attention, and activity, to render it capable of yielding any other produce than that indigenous to it.

The term "gault" is used by farmers and others for almost any clean, tenacious clay, consequently Lias and Oxford Clay are called Gault by them. Nor is it surprising that this should be so, the physical and agricultural features of all being much alike. The Gault makes a good brick, hard and durable, the quality excelling the appearance. Brickpits are opened in it at Harlington and places south of Leighton Buzzard; and also at Arlesey, on the eastern border of the county, where it is extensively worked; parts of that locality being dug for coprolite in addition to being prepared for brickmaking purposes.

With reference to the Ampthill Clay, it is somewhat doubtful whether this is a distinct formation from the Oxford Clay. There is a thick mass of it exposed in the cuttings of the Midland Railway near Ampthill Station. At the northern entrance to the tunnel there are several noticeable layers of stone, manifestly concretionary, and containing fossils (principally *Exogyra*). These concretionary stones lie amongst the clay in a contrary way to the bedding. To the south of the tunnel the clay is blacker, and contains Kimeridge forms of fossils. Similar, though thicker, concretionary beds, considered as representing the otherwise absent Corallian series, occur amongst the clay in the brickyards about St. Ives, and places west of Cambridge. Professor Seeley has correlated the clay with septarian concretions in the Ampthill cutting, with those at the St. Ives and neighbouring brickyards, localizing it as the Ampthill Clay. It may, therefore, be considered as a passage-bed between the Oxford and Kimeridge Clays.

Before quitting this section I must not omit to mention a character of the Ampthill Clay, which, I think, justifies me in bestowing on it the term " troublesome "—an epithet which everyone who has anything to do with that portion of the line will endorse. This is its sensitiveness to the weather, the result of which is that the cutting presents an appearance of disorder, more compatible with that of a line in course of construction (which, indeed, in one sense, is really the case) than with that of an established road, over which for so long so many trains have daily run. As is well known, huge masses of the clay become detached from the sides of the cutting, and slide forward, with a tendency to fall upon the line. This is frustrated by the expedient of burning the clay on the spot, constructing with it platforms at the foot of the slopes. These present a rough surface, arrest the progress of the sliding mass, and preserve the rails intact. Where so large a surface of clay is exposed to the sun's heat, as at the Ampthill cutting, it is speedily cracked all over. These cracks become open joints and separate the clay into pieces, which in turn become sodden and undermined in wet seasons, or after frost. In consequence of the water that has percolated, the pieces first totter and then fall, as the landslip becomes complete. It is not unlikely that the intercalated concretionary beds assist the destruction by absorbing and letting water through; the neighbouring clay becoming too soft to sustain these beds, so that all come bodily down together. The protecting power of grass in averting denudation is known to be very considerable. If grass were grown on these slopes it is not improbable that, as the surface was added to by the growth of the vegetation, the slides would at least be of less frequent occurrence, even if they were not entirely stopped.

The main mass of clay in the county consists of two distinct argillaceous deposits—Oxford Clay, forming the principal grazing districts, and Boulder Clay, including the principal wheat-producing districts. Wherever the former rises into isolated hillocks, or occupies high ground above the plain, the Boulder Clay is spread upon it, irregularly in patches, or covering it entirely in a continuous sheet. It will be most convenient to describe each separately.

Except where it is denuded in the valley of the Ouse around Bedford, the Oxford Clay occupies a low-lying tract of country of considerable breadth in Bedfordshire, best described as the Vale of Bedford. It is, as it were, the border land that separates the Cretaceous from the Jurassic system of rocks. In the scenery of an Oxford Clay country there is little interesting or inviting. In traversing districts such as these, we look in vain for natural sections or exposures ; no cliffs, or scarps, or rugged rocks, diversify and beautify the scene. Perhaps as far as the eye can see, interminable pastures and rich grazing lands present themselves to view ; for this is heavy land, hard to cultivate, and kept, therefore, for the most part, in permanent grass. On the slopes, or on hilly spots the soil is often lighter, from receiving a downwash from the hills above, or by retaining on its surface some lingering relic of the Boulder Clay. In such places the pastures give way before the plough, and arable land sometimes of surprising fertility exists. In spite, however, of such occasional changes, the scene as a whole is uninviting. With what pleasure we hasten to leave the dull monotony of the place, and ascend the Greensand hills above! There we may roam amongst thickly-wooded, sandy knolls, pink and purple heaths, russet fern and dark plantations, through which the brilliant tints of the sand gleam brightly.

On such heights as these the Boulder Clay reveals itself, first, perhaps, in patches only, barely more than concealing the rocks around ; then, as the escarpment is left for the open table-land ahead, the main mass of clay is entered on, and this may constitute the soil of the entire elevated region.

Nowhere is the universality of the Boulder Clay on hilly lands seen to greater advantage than in the immediate neighbourhood of Bedford. It frequently happens that Boulder Clay lands are interrupted by isolated spots, or even by considerable spreads, of gravel and sand, the outcrops of beds in, or belonging to, the Glacial Drift, of which the Boulder Clay is a part. There is, however, a district of hilly clay overlooking the town, and extending beyond the limits of the county, where sand, gravel, or any other accumulation than the Boulder Clay itself, is almost, if not completely, unknown. I exclude, of course, the gravels and loams in the bottoms of the valleys, as these belong to an age apart from that of the Boulder Clay.

When we consider the great extent of country covered with this clay—from the river's edge at Foster's Hill, upwards, in everrecurring undulation, ridge, and plateau, by Stagsden, Astwood, beyond The Chase, to the confines of Northampton and the Nen; again, by Thurleigh, Wilden, Souldrop, and Risely, beyond the county, to the pasture plains in Huntingdon—we realize in what a land of clay we dwell, and how widely spread and universal this deposit is. Further, when we reflect that it is but in part indigenous, we seek to know from whence it came, and how it travelled hither. Of what does the Boulder Clay in Bedfordshire consist? A mass of very hard, blue, or whitish clay, in which are many stones of chalk and of other rocks. Some 20 feet were exposed in making the reservoir on Foster's Hill, where we found many of the chalk stones, with surfaces grooved and polished. Besides chalk and chips of flint, there were fragments of quartz, granite, and mica-schist, scattered septaria, and boulders.

Clearly much of this has travelled far from home, for we see, mixed with the waste derived from the immediate neighbourhood, the chalk perhaps of Norfolk and from the Lincoln Wolds, and fragments, perhaps, from ancient volcanic centres amongst the Cumberland or Scottish mountains. Truly a heterogeneous mass, in which running water has had no part, for there is no sorting here of the heavy blocks and finer particles, but one and all are brought together in a promiscuous mass. We can most readily imagine this to be the result of the scouring of the old land by ice in the form of glacier or of land-ice.

From our elevated position on Foster's Hill we cast our eyes beyond the debateable soil on which we stand, and in imagination see hill and plain alike concealed by ice, which, as it pushes steadily and slowly southwards, carries beneath it, and distributes as it melts, the mud and stones accumulated by the grinding of the rocks under so great a weight of moving ice. We can realize, therefore, how the Boulder Clay can be the residue both of local rocks and of those over which the land-ice has travelled in the earlier stages of its journey.

Mr. H. B. Woodward, in his 'Geology of England and Wales,'* says of the Chalk in Norfolk that "the surface is seen to have weathered in a very rubbly form to a depth of six or eight feet; and this weathered chalk would furnish, *ready made*, the very material for the Boulder Clay." Indeed, in Norfolk the Boulder Clay is little else than reconstructed chalk. The Boulder Clay of

---

* Second Edition, 1887, p. 485.

Lincolnshire, too, is sometimes intensely chalky, and many old pits remain, that were dug to marl the sandy soils that not unfrequently lie upon it. There was so much of the whiteness of chalk about these pits that at a little distance it was difficult to say whether they were in Boulder Clay or in Chalk.

In the second cutting, north of Sharnbrook Station (Bedford and Leicester branch), there is a large mass of churned-up chalk, enclosing flints, exposed amongst the Boulder Clay laid bare in the deep cuttings characteristic of that section of the line. It affords not only a good illustration of the source from whence the Boulder Clay derived its chalk, but is also an instance of an erratic block transported thither by ice. At Wymington, too, on this line the Boulder Clay is intensely chalky, fully as much as that in many parts of Norfolk.

Boulder Clay, as a rule, makes an excellent dressing for many kinds of land, as it rapidly disintegrates by exposure to the weather. It is also an excellent soil in itself, and sufficiently fertile when well drained. Being lightened by the presence of stones, it is by no means a heavy clay like the Oxford. It is especially true of it that the more it is stirred up so as to expose the chalk and other calcareous stones to the disintegrating effect of the weather, the more friable and valuable the land becomes; and, however true the saying may be, that clay soils are "season soils"—the term "sure soils" being restricted to alluvial lands—in the majority of cases "deep ploughing, steam cultivation, and drainage have produced, or will produce, great additional fertility." None of us, however, question its being "dirty in wet weather and loose and dusty in dry weather," as is written of it in a report on Bedfordshire of the year 1808.

Harvest may be late on Boulder Clay lands; but it makes a good soil, especially for corn.

In the 'Memoirs Geol. Survey, Cambridge,' Mr. Jukes-Browne says "that most unaccountably there is great hesitation among farmers in allowing their ploughs to go down to this clay. In many parts they will not turn the 'raw earth' up if they can help it. Notwithstanding, there is no surer means of improving the land, if done gradually and with discretion. There are places where the sudden introduction of deep ploughing has not been beneficial, but in the majority of cases this is only temporary, and in time great additional fertility will result from deep stirring the clay subsoils, and especially on the Boulder Clay."

Boulder Clay does not lie indiscriminately everywhere, as it probably did of old. It stops short on the brow of the hills; the denuded edges of the underlying rocks being generally bare of this drift. This is to be accounted for by supposing that the River Ouse in forming its valley scooped out the Boulder Clay together with a considerable thickness of underlying rock.

There are many spots, such as railway-cuttings, roadsides, pits, and ponds, where the Boulder Clay can be observed. It is almost always to be seen newly dug up in the upper part of the Cemetery. Permeable to some extent, springs of good quality, though hard, issue at its junction with the underlying Oxford Clay, which is too retentive to allow of percolation.

On the eastern range of hills there is, as already said, a good deal of sand and gravel, singularly absent from amongst this clay on the north and west. As an exception to this may be mentioned an isolated spot, or fragment, of very coarse gravel, at Grindstone Hall, Turvey. The general appearance resembles that at Gravel Pit Plantation, to be noticed shortly. There is, however, perhaps, a greater variety of stones. I noticed besides chalk and flint, basalt, granite, Carboniferous Limestone (glaciated), ironstone in the form of nodules, septarian stones, and fossils from the Lias and local Jurassic rocks.

From Battlesden Park End to the Lodge Gates on the Woburn Road there is a long tongue or ridge of Boulder Clay capped with gravel. Again, in the pits about Heath-and-Reach, gravel lies both in and over the clay. This gravel is mainly coarse ; having large blocks and balls of Chalk and Gault in it. A most excellent and instructive section is afforded at the pit in Gravel Pit Plantation, to the north of Ampthill, on the Bedford road, which was visited by the Association on the occasion of their former Excursion to Bedford and Ampthill. In the second cutting north of Harlington Station (the first is in Gault), there are upwards of 20 feet of clay (with glaciated chalk, flint chips, limestones, and granite) cut down to the Gault, from which it is separated by a thin layer of sand. The largest gravel patch appears at Toddington, where it covers two square miles of the Boulder-Clay hill on which the village stands. Ampthill, and the sandy heights at Millbrook, are speckled with gravel and Boulder Clay.

At the Wyminton tunnel and the cuttings about Sloudrop Boulder Clay is in great force, attaining a thickness of 50 feet, which is probably its maximum thickness in the county. It lies thick too about Wotton and the lands around Cranfield, from whence it ends off on the brow of the hills, where these encircle the plains below.

There are no good sections of Oxford Clay (if we except Ampthill) to be examined, for, as said before, it rarely shows itself. It is laid open, however, in plenty of brickyards, and constantly turned up in ditches and cuttings for drains. It is to the brickyards, therefore, we must turn for opportunities to describe it.

It nearly always appears as a pale-blue, sometimes somewhat shaley, clay, yellowish at the top from being weathered; with *Belemnites*, *Ammonites* (unfortunately seldom perfect), several species of oyster, Gryphites (too numerous in some brickworks), especially the characteristic *Gryphæa dilatata*, other shells, and the bones and teeth of *Plesiosaurus* and *Pliosaurus*, whose vertebræ and swimming paddles are abundantly disseminated through this clay. Fossil wood, in which the fibrous structure is very evident, also occurs, being in plank-like pieces from compression, sometimes six feet or more in length. There is a plaster cast of a paddle-bone, a femur of *Plesiosaurus eurymedus* (described by Prof. Phillips in the 'Outlines of Geology,' p. 315), the property of the Bedfordshire Natural History Society; the original, which was dug from the clay at the Clapham Brickyards, being, I believe, in the Woodwardian Museum, Cambridge. E. R. Williamson contributes a paper, entitled "A Short Account of a Fossil Skeleton of a Plesiosaurus lately discovered near the Town of Bedford," to the 'Magazine of Natural History,' Vol. vi, p. 422, 1833. A skeleton of *Plesiosaurus*, or a considerable portion of one, from the Oxford Clay Brickworks at Kempston, was recently described by R. Lydekker, Esq., at the Geological Society, as a link between *Plesiosaurus* and *Pliosaurus*.

At Bone End and Box End Brickyards, Kempston, and at several others, there are many beautiful crystals of selenite, which the workmen call "glass." A yellow crystalline band may be sometimes seen amongst the clay, and on being examined is found to consist of the residue of shells thickly coated with minute selenite crystals, which have developed around them as they slowly decomposed. Nodules of iron pyrites, and calcareous concretions, the "ginger" of the workmen, also occur.

It is often necessary to sink a long way into this clay in order to obtain water, and after all it is as likely as not to be bad or to smell, the mineral ingredients impregnating the water to such an extent as to render them more valuable for medicinal purposes than for ordinary consumption. Numerous mineral springs issue, or are met with in wells, throughout the Oxford Clay area of this county.

At Pollox Hill, on the Gault, there is a so-called "Gold Mine," but I am inclined to regard it as being some form of iron pyrites—marcasite, for instance.* Nevertheless, "Gold Mine" is on the Ordnance map.

The brickworks on the Clapham Road, Kempston, Bletsoe, Sharnbrook, and others further still from Bedford, are opened just beneath a bed of yellow sand and bluish loam—the "mild clay" of the builders. This is mixed to some extent with the strong clay below (Lower Oxford) in the preparation of bricks. This admirable exposure of Kellaways rock—for such the sandy bed has been found to be—is characterized at Bedford by "doggers," or hard masses of calcareous sandstone, that lie very prominently amongst the sand and loam. This basement bed to the Oxford Clay was first brought into notice by William Smith. In olden times, owing to the difficulty of transporting road-metal, local stones were much more used than they are now; and thus the rock at Kellaways was then used for this purpose.†

Beyond Bedford, which partly stands on Kellaways Rock, this rock can be traced up the valley as a fairly persistent bed or belt of sandy land, from which the hard stone or dogger is seen protruding. It closely follows the windings of the Ouse on both sides of that river. At Turvey, just above the Cornbrash, there is a considerable spread of it, locally known as "white land," in dry weather easily recognizable even from a distance by its colour. It is here abundantly fossiliferous, the doggers at the West Barnes brickyard being little else than shells and shelly débris in a sandy matrix. The casts and tubes of annelids are almost invariably present on the surfaces of these doggers, and this is very characteristic of the rock about Bedford.

---

* 'Magna Britannica,' Vol. ii, p. 19, says, with reference to Pollux Hill: —"It has been said, indeed, that gold was formerly discovered at Pollux Hill, and that an attempt was made to work a mine there; but it is probable that the idea originated in mistake. Woodward mentions 'a mass of yellow shining talc, with a yellow earthy matter mix't with it,' as found at this place. Probably a similar substance was mistaken for gold by persons not skilled in mineralogy."

† Mr. H. W. Bristow, F.R.S., informed me in a letter written in 1885 that "there is no Kellaways rock now at Kellaways. I understood it to have been all quarried away for roadstone years ago."

VISIT TO THE BRITISH MUSEUM (NATURAL HISTORY), DEPARTMENT OF GEOLOGY.

SATURDAY, MARCH 17TH, 1888.

DEMONSTRATION ON EDENTATA, MARSUPIALIA, AND FLIGHTLESS BIRDS, BY DR. HENRY WOODWARD, LL.D., F.R.S., F.G.S., KEEPER OF THE DEPARTMENT.

(*Report by* DR. WOODWARD.)

Dr. Woodward pointed out to the Members that the South-East Pavilion, where they were assembled, contained three most interesting groups of animals, all having modern representatives in the regions where their fossil remains have been found ; but the living forms being of much smaller size than their ancestors. These three groups were the *Edentata* of America, the *Marsupialia* of Australia, and the extinct flightless birds of New Zealand.

In this gallery are arranged the remains of the various extinct genera of Edentata from America belonging to the Sloths and Armadillos, and remarkable for their gigantic size when compared with their small living representatives. All the animals of this order are vegetarians in diet, except the Ant-eaters and the Armadillos, the former of which subsist on the White Ant, and the latter on roots and the grubs of insects. The name of the order is misleading, as these animals are not entirely toothless, with the exception of the *Myrmecophaga,* the frort teeth only being wanting in the majority ; the cheek-teeth have permanent pulps always growing up as they are worn away at the crown.

The Megatheriida, represented by *Megatherium, Mylodon, Scelidotherium, Megalonyx,* and *Cœlodon,* present characters intermediate between the existing Bradypodidæ (Sloths) and the Myrmecophagidæ (Ant-eaters), combining the skull and dentition of the former, with the structure of the limbs and vertebral column of the latter. [One species of *Scelidotherium* approximates in its cranial characters to the Myrmecophagidæ.] Almost all the ancient forms were of gigantic size, *Megatherium* being larger than any Rhinoceros. The teeth in *Megatherium* are prismatic in form (quadrate in transverse section), and composed of hard dentine, softer vaso-dentine, and cementum, so arranged that, as the tooth wears, the surface always presents a pair of transverse ridges, thus producing a dental apparatus well suited, like the molar teeth of *Dinotherium*. *Tapirus*, etc., for triturating vegetable food. *Megatherium* has five such teeth on each side in the upper, and four on each side in the lower jaw, as in the modern Sloth: *Cœlodon* has one tooth less on each side both in the upper and lower series.

None of these forms were arboreal in habit, but they were probably all phytophagous in diet, subsisting upon the leaves and young branches of trees which they pulled down within their reach. The tongue was certainly very long and retractile, and would, like that of the Giraffe, have largely assisted the animal in bringing the food to its mouth. Most of these remains have been obtained from the Pleistocene deposits in the Argentine Republic; but they have also been procured from Patagonia, Brazil, Uruguay, Chili, and Bolivia, all in South America, and from nine different States in the United States of North America.

A nearly perfect original skeleton of *Mylodon gracilis*, Owen, has been set up in this gallery beside the restored skeleton of *Megatherium*, so that we see in juxtaposition examples of two of the largest genera of these great extinct ground-sloths, once the denizens of the great tropical forests of America, and represented to-day by the tree-sloth (*Bradypus*), an animal not larger than a dog in size, a skeleton of one of which is placed in the adjoining wall-case for comparison with the *Megatherium*.

In addition to the series of remains of the gigantic Ground-Sloths, we may also notice the remains of several genera of extinct gigantic Armadillos, from the Pleistocene deposits of South America.

These large extinct genera differed from the modern Armadillos in having none of the bands or joints in their coat of mail, by means of which the living forms are enabled, when attacked, to contract the body into the form of a ball. In most of the extinct species the carapace is composed of polygonal or quadrangular bony scutes, closely united by their sutures into a solid buckler, and the caudal portion is enclosed in a complete bony tail-sheath. The top of the head is also protected by dermal plates of bone.

The cheek-teeth are sixteen in number, four above and four below on each side, incisors not being developed; they have two deep grooves on either side dividing them into three nearly distinct lobes. The facial portion of the skull is extremely short, and the zygoma has a long descending maxillary process just beneath the eye.

The vertebral column beneath the carapace is almost entirely anchylosed into a long tube, and is confluent with the under surface of the dermal armour, to which the ribs are also united. There is a complete joint at the base of the neck, the seven vertebræ of which remain free and moveable ; and in the tail all the vertebræ are anchylosed together except the first four behind the sacrum.

Several genera and numerous species have been determined, the latter being distinguished principally by the variations in the ornamentation and form of the tesseræ of the carapace and the tail-sheath.

The typical genus is *Glyptodon* (sculptured-tooth), so named by Sir Richard Owen in reference to the sculptured aspect of the grinding surface of the teeth.

The restored carapace and skeleton of *Glyptodon* (Glass-case Q) measures from the snout to the end of its armour-plated tail, following the curve of the back, 11 feet 6 inches, the tesselated body-shield being 7 feet in length and 9 feet across, following the curve of the middle of the back.

The living six-banded Armadillo is less than a foot in length. It was represented by the extinct genus *Chlamydotherium*, detached plates and bones of which have been found in abundance in the caves of Minas Geraes, Brazil.

A nearly entire carapace and tail-sheath, partly restored, of *Hoplophorus*, an allied but smaller genus of extinct Armadillos, is exhibited in Wall-case 20.

Judging by the numbers of remains of these large extinct Edentata which have been collected from time to time, we have evidence, not only of their great abundance and wide geographical distribution in the tropical and subtropical wooded regions of America, but also of the vast numbers of these huge animals which must have perished in floods from their having been unable to climb into trees to escape destruction, after the manner of their modern representatives, the Tree-sloth and Ant-eater.

The Edentata, although so largely represented in America, are not strictly confined to that region, but are represented in South Africa by the " Cape Ant-eater " (the " Aard-Vark " of the Dutch settlers), the "Pangolins" or Scaly Ant-eaters belonging to the genus *Manis*, which have a very wide range over the greater part of Africa, and in India from the Himalayas to Ceylon, Sumatra, Java, Southern China, Amoy, Hainan, and Formosa. An ancestral form of *Manis* has been found fossil in the Siwaliks, in Sind and in Madras, whilst *Macrotherium giganteum* has been discovered in the Upper Miocene of Eppelsheim and the Middle Miocene of Sansan, France.

Such a wide geographical distribution in this family of Edentata naturally implies a correspondingly great antiquity in geological time for this singular group, which must have witnessed most marked changes in the configuration of the ancient continents, on parts of which its modern descendants now find themselves so widely separated geographically.

MARSUPIALIA.—The Marsupialia or "pouched animals" comprise a curious series of mammals, offering at the present day considerable variety in form, but all characterized (with the single exception of *Thylacinus*,* the "Tasmanian wolf") by possessing a pair of long, slender, "epipubic" bones attached to the anterior edge of the pelvis, commonly called "marsupial bones," but bearing no special relation to the external pouch or *marsupium*,† and present alike in both sexes. The young in this order are brought forth in a blind and very imperfect condition; and, in those forms in which that organ is present, are then placed by the parent within a fold of the integument, which forms the "pouch" or *marsupium*, whence the order derives its name. Within this pouch the mammary glands are situated, and to the prominent nipple the young one at once becomes firmly attached and remains so for some time after birth. In other cases, as among the Opossums, the young are carried on the back of the mother, on which they are supported by twisting their tails round that of the mother. The posterior angle of the lower jaw is generally bent inwards. There are always true teeth implanted in the usual manner in both jaws, and divisible into incisors, canines, premolars, and molars, but they vary much in the different families.

There is no vertical displacement and succession of the teeth, except in the case of a single tooth on either side of each jaw, which is always the hindmost of the premolar series, and is preceded by a tooth having the character of a true molar, which is the only one comparable to the milk-tooth of the higher mammalia.

---

* In *Thylacinus* the epipubic bones are cartilaginous only.

† There is no pouch or marsupium in the Opossums.

The Marsupials are primarily divisible into two great sections, the first being provided with numerous small incisors and well-developed canines (known as the Polyprotodont[*] division), containing the carnivorous group of Marsupials, such as the Opossums, Dasyures, Thylacines, and Bandicoots ; in the second (known as the Diprotodont[†] division), comprising the vegetable feeders, as the Kangaroos, Phalangers, and Wombats, the central incisors are very prominent and are the only ones in the lower jaw, while in the upper jaw the lateral incisors and canines are very subordinate in function and may be absent.

As typical representatives at the present day of the Polyprotodont (carnivorous) division we may mention the *Didelphiidæ* or true Opossums, which differ from all other Marsupials in the fact that they are found living on the American Continent, whereas the great home and centre of the Marsupialia is Australia. They are mostly carnivorous or insectivorous in their diet, and arboreal in their habits. Eight existing species (chiefly known in a fossil state by the jaws) are represented in the collection from the caverns of Minas Geraes, Brazil, etc. Professor Cope has described a species, *Didelphys fugax*, from the Miocene of Colorado, under the name of *Peratherium*. Ten extinct species are represented from the Lower Miocene, the Oligocene, and the Upper Eocene of France, and one from the Upper Eocene of Hordwell, Hampshire. The genus *Chironectes* is also represented from Minas Geraes, Brazil, by the living species. But the greatest development of the Marsupialia at the present day, as well as in Tertiary times, is to be found on the continent of Australia. The carnivorous genera *Thylacinus*, *Sarcophilus*, and *Dasyurus* are all represented in the collection, by remains from the caves of Queensland and the alluvial deposits of New South Wales.

Of the Diprotodont type no fewer than ten species of Wombats (*Phascolomys*) are known and described by their fossil remains. They varied in size from that of the existing species up to *Phascolonus gigas*, which was equal in size to a Tapir, but of much stouter build. Intermediate between these great Wombats and

[*] From πολύς, πρῶτος, and ὀδούς, "with many front teeth."

[†] From δι=δίς, πρῶτος, and ὀδούς, "with two front teeth."

"*The Native 'Lion' of Australia: a very gentle beast and of good conscience.*"

"What, with all due respect to my friend's profound skill, I most particularly doubt is, that the *Thylacoleo* was a lion, or a beast of prey of any sort. Nay, I even doubt whether the famous molar, on which the Professor so much relies, was 'flesh-cutting' in the sense that the first molar of a lion or tiger is 'carnassial.' Indeed, I know not any carnivorous mammal—certainly not a lion or tiger—with a premolar like that which the Professor figures as characteristic of his *Thylacoleo*. I need scarcely say that the native cats, and all existing marsupials that are known to be carnivorous, possess, like the true placental *carnivora*, laniary molars furnished with cusps more or less sharp. Whereas the tooth in question is a very broad and rather curvilineal chisel, having a sharp, even summit, admirably adapted for cutting twigs, but with nothing laniary about it."

He then goes on to show the resemblance of the tooth to that of *Hypsiprymnus*.

Those who are interested in the question should consult Prof. Flower's Memoir "On the affinities and probable habits of the extinct Australian Marsupial *Thylacoleo carnifex*" (Owen) in the 'Quarterly Journal of the Geological Society' for 1868, Vol. xxiv, p. 307, and Article "Mammalia" (Marsupialia), 'Encyclop. Britannica,' 9th Edition, Vol. xv, pp. 378-383.

Of the *Macropodidæ* found fossil in Australia, we may mention the following species whose remains are preserved in the collection, viz.:—

Æpyprymnus rufescens. *Macropus*, thirteen species of which the names *titan*, *altus*, *anak*, are intended to convey Sir Richard Owen's idea of the great size which some of these old kangaroos attained. In the Older Tertiary strata, in the Purbeck beds, the Stonesfield slates, the Rhætic beds, of this country; in the Trias and Jurassic of America, the Keuper of Germany, and the Trias of the Cape, a remarkable series of fragmentary remains of small mammals have been met with, which from the peculiarities of their dentition, have generally been regarded as most probably belonging to the Marsupialia, many of whose members, like the Opossums, the Bettongias, the *Myrmecobius*, and the *Perameles*, were of small size and of insectivorous diet. Similar forms also occur in the Tertiary of South America.

The following is a list of the more important of these Secondary and Older Tertiary genera and species of Europe and America; those belonging to the Polyprotodont division being distinguished by an asterisk :—

Allodon fortis, Marsh,	Upper Jurassic, Wyoming.
„ *laticeps*, Marsh,	„ „
Ctenacodon potens, Marsh,	„ „
„ *serratus*, Marsh,	„ „
„ *nanus*, Marsh,	„ „
**Dryolestes priscus*, Marsh,	„ „
„ *vorax*, Marsh,	„ „
„ *arcuatus*, Marsh,	„ „
„ *obtusus*, Marsh,	„ „
„ *gracilis*, Marsh,	„ „
**Stylacodon gracilis*, Marsh,	„ „
„ *validus*, Marsh,	„ „
**Asthenodon segnis*, Marsh,	„ „
**Laodon venustus*, Marsh,	„ „
**Diplocynodon victor*, Marsh,	„ „
**Docodon striatus*, Marsh,	„ „
**Enneodon crassus*, Marsh,	„ „
„ *affinis*, Marsh,	„ „
**Menacodon rarus*, Marsh,	„ „
**Tinodon bellus*, Marsh,	„ „
„ *robustus*, Marsh,	„ „
„ *lepidus*, Marsh,	„ „
**Triconodon bisulcus*, Marsh,	„ „
**Priacodon ferox*, Marsh,	„ „
**Paurodon valens*, Marsh,	„ „
**Dromatherium sylvestre*, Emmons,	Trias, N. Carolina.
**Microconodon tenuirostris*, Osborn,	„ „
Neoplagiaulax eocænus, Lemoine,	Lr. Eocene, Rheims.
„ *marshi*, Lemoine,	„ „
„ *copei*, Lemoine,	„ „
„ *americanus*, Cope,	Eocene, U.S.A.
Ptilodus mediævus, Cope,	„ New Mexico.
Polymastodon taoensis, Cope,	„ „
„ *attenuatus*, Cope	„ „
„ *latimolis*, Cope,	„ „
Plagiaulax becklesii, Falconer,	Middle Purbeck, Swanage, Dorset.
„ *medius*, Owen,	„ „ „ „
„ *falconeri*, Owen,	„ „ „ „
„ *minor*, Falconer,	„ „ „ „
Tritylodon longævus, Owen,	Trias., ? South Africa.
„ *fraasii*, Lyd.,	Triassic bone bed, Strasbourg.

Microlestes moorei, Owen,	Rhætic, Frome, Somerset.
Bolodon crassidens, Owen,	Middle Purbeck, Swanage, Dorset.
**Triconodon mordax*, Owen,	„ „ „ „
„ *ferox*, Owen,	„ „ „ „
„ *major*, Owen,	„ „ „ „
**Phascolotherium bucklandi*, Broderip,	Lr. Jurassic, Stonesfield, Oxon.
**Amphilestes broderipii*, Owen	„ „
Amphilestes (?) sp.	„ „
**Amphitherium prevosti*, Blainville	„ „
**Amblotherium soricinum*, Owen,	Middle Purbeck, Swanage, Dorset.
„ *talpoides*, Owen,	„ „ „ „
„ *mustelula*, Owen,	„ „ „ „
**Achyrodon nanus*, Owen,	Middle Purbeck, Durlstone Bay, Swanage, Dorset.
„ *pusillus*, Owen,	„ „ „ „
**Peramus tenuirostris*, Owen,	„ „ „ „
**Stylodon pusillus*, Owen,	Middle Purbeck, Swanage, Dorset.
„ *robustus*, Owen,	„ „ „ „
**Leptocladus dubius*, Owen,	„ „ „ „
**Spalacotherium tricuspidens*, Owen,	„ „ „ „
„ *minus*, Owen,	„ „ „ „
**Peralestes longirostris*, Owen,	„ „ „ „
Stereognathus, Owen,	Stonesfield Slate.
**Didelphys* (?) *fugax*, Cope,	Miocene, Colorado.
„ *affinis*, Gerv.,	Upper Eocene, Vaucluse, France.
„ *antiqua*, Gerv.,	„ „ „
„ *arvernensis*, Croizet,	Lr. Miocene, Puy-de-Dôme, France.
„ *blainvillei*, Croizet,	„ „ „ „
„ *exilis*, Gervais,	„ „ „ „
„ *lemanensis*, Filhol.,	„ „ Allier „
„ sp. (c.),	Upper Eocene, Hordwell, Hants.
„ *lamandini*, Filhol.,	Upper Eocene (?), Caylux, France.
„ *aymardi*, Filhol.,	„ „ „ „
„ *cadurcensis*, Filhol.,	„ „ „ „
Chirox plicatus, Cope,	Cretaceous, U.S.A.
Meniscossus conquistus, Cope,	Cretaceous, Dakota, U.S.A.
Abderites meridionalis, Ameghino,	Tertiary, Patagonia.
Acdestis oweni, Ameghino,	„ „
Palæotheutes lemoinei, Ameghino,	„ „
„ *pachygnathus*, Ameghino,	„ „
„ *intermedius*, Ameghino,	„ „
„ *pressiferatus*, Ameghino,	„ „
„ *minutus*, Ameghino,	„ „
Microbiotherium patagonicum, Ameghino,	„ „
„ *tehuelchum*, Ameghino,	„ „
Stilotherium dissimile, Ameghino,	„ „

" This portentous, though imperfect list " (writes Mr. Lydekker to the author), " it is certain, will have to be largely reduced, and some steps have already been taken in this direction. Some of the generic names, moreover, like *Diplocynodon* and *Stylodon*, are pre-occupied, on which account they are not entitled to stand; and another term has already been proposed to replace the former, while the latter has been identified with *Stylacodon*. Again, although the Diprotodont types—the *Multituberculata* of Professor Cope—have till recently been included in the sub-order Diprotodontia, considerations have been advanced by Professors Cope and Osborn calling in question the correctness of this reference. These considerations are based on the curious resemblance existing between their molar teeth and the rudimental tooth-gums of *Ornithorhynchus;* and also on the circumstance that while in the Diprotodont Marsupials it is the first pair of incisors that persists and becomes hypertrophied, in the Multituberculata it is the second pair which becomes so modified. Hence it has been suggested that these forms may possibly prove to be Monotremes, or perhaps we should rather say Prototherians."

With regard to the Polyprotodont types of pre-Tertiary age, if we except *Dromatherium* and *Microconodon*, which from their extremely generalized characters may indicate a lower type of organization, there is a strong probability that at least the majority are truly Marsupials, although opinions have recently been expressed against this view. The increase in the number of lower incisors above the normal three pairs of the higher mammals, and also the large number of true molars occurring in many of these forms, are characters unknown elsewhere than in the marsupials, and are therefore strong points in favour of the marsupial nature of their owners.

The recent observations of Professor Osborn, of which only a preliminary notice has yet appeared, have done much to reduce the number of generic types in this group, and it is probable that still more remains to be done in this direction. It will suffice, however, to mention here that these observations show that *Stylodon* and *Stylacodon* have been founded upon a view of one side only of the lower jaws, of which the other side has been described under the names of *Amblotherium*, *Achyrodon*, *Peramus*, and *Dryolestes ;* so that these and perhaps some other types may be reduced to two genera at the most. Again, it now appears to be practically

(ii) Cycloid scales.

Osmeroides ; *Acrognathus* ;

Cladocyclus ; *Calamopleurus* ;

(iii) Ctenoid scales.

Beryx ; *Hoplopteryx* ; *Stenostoma*

(iv) Ganoid scales.

(A) Rhombic.

Lophiostomus ; *Neorhombol*

Gyrodus ; *Cœlodus* ;

(B) Round and much ornamented

Macropoma.

SPINES.

(i) Round, ribbed.

Cœlorhynchus.

(ii) Laterally-compressed, smooth.

Drepanephorus.

EXPLANATION OF

FIG. 1.—*Neorhombolepis excelsus*, A. S. Wo
Upper Halling, Kent. *op.* operculum. *p.*
scales. *S. op.* suboperculum. (B.M., No.

FIG. 2.—Scales of the so-called *Lepidotus*
size; Blue Bell Hill, Burham, Kent. Coll
F.G.S.

FIG. 3.—Portion of dentition of *Stratodus*
size; Glynde, Sussex. 3*a*. Section of tooth

FIG. 4.—Anterior portion of left dentary
two series of teeth, nat. size; Lower Chalk
depth of the bone is not clearly indicated,
half-superior, half-lateral. (B.M., No.

FIG. 5.—Skull and mandible of
view, nat. size; Lewes. *d.* Dentary bone
(B.M., No. P. 5,415.)

FIG. 6.—Palato-pterygoid arcade of
ectopterygoid. *entp.* entopterygoid.

FIG. 7.—Scute of "lateral line" of
times nat. size; Norfolk. Collection of

FIG. 8.—Scale of *Pachyrhizodus*,
1,808.)

FIG. 9.—Pelvic fin, and fragment
nat. size; Kent. (B.M., No. 39,429

FIG. 10.—Tooth of *Ancistrodon*,

certain that the suggestion made by Mr. Lydekker, that the upper jaw on which the genus *Peralestes* was founded belongs to the same form as the lower jaw which was made the type of *Spalacotherium*, is the correct explanation; and it may be added that Professor Osborn now considers that the upper jaws, on the evidence of which he recently proposed the name *Athrodon*, belong to *Amblotherium*, or to a closely-allied form.

(For an account of the Flightless Birds of New Zealand see 'Proc. Geol. Assoc.,' Vol. ix, No. 5, pp. 352-376, 1886.)

VISIT TO THE NATURAL HISTORY MUSEUM, BOTANICAL DEPARTMENT.

SATURDAY, APRIL 7TH, 1888.

DEMONSTRATION ON FOSSIL ALGÆ, BY MR. W. CARRUTHERS, F.R.S., KEEPER OF THE DEPARTMENT.

(*Report by* THE EDITOR, *revised by* MR. CARRUTHERS.)

The Members having assembled in the Herbarium, Mr. Carruthers, in welcoming the Association once more to the Department, said that he had chosen for himself an easy task, his subject being a limited one. Algæ must have lived in the earliest ages, since we have evidence of an abundance of marine animal life, and animals, giving off carbonic acid gas, which plants remove from the air, and requiring pure air as well as food, can only exist together with plants. In the Archæan rocks also carbon is abundant, especially as graphite, Sir J. W. Dawson believing that this series contains as much of this element as does the Carboniferous. It is true that this carbon is in an unorganized condition; but marine vegetation with the remains of the contemporary animals must have been the sources from which it was derived. Many Algæ have been described from the older rocks; but they are in many cases the tracks of worms, mollusks, or crustaceans. Dr. Nathorst, a Swedish botanist, has shown that algoid markings agreeing in form with the so-called Algæ of the older rocks occur on the shores of the Baltic and are entirely inorganic, being produced by the moving water, causing plants or other obstacles to form markings on the shore. Count Saporta, however, still holds such markings to be Algæ. As to *Oldhamia*, two forms of which have been described from the Cambrian rocks of Ireland, the material available is most imperfect, outline only and no structure being preserved. It may possibly be a plant.* The earliest undoubted Alga is that found by Sir J. W. Dawson many years ago in Upper Silurian and Devonian beds, reaching a diameter of two or three feet, with, in many cases, well preserved structure and situated perpendicularly to the strata. As he believed the tissue consisted of wood-cells, marked with coniferous discs and thickened with spiral threads, Sir J. W. Dawson referred this plant to the Yews and named it *Prototaxites*. In specimens, however, which, some fifteen years ago, were received from Dawson, the speaker had found that there were no true wood-cells, but that the tissue consisted of long cells matted together by transverse smaller cells (mistaken for spiral threads), recalling the structure of the *Siphoneæ* as in *Codium*. A *Rhipilia* recently found by Dr. Anderson in the Mergui Archipelago, having a stout stem buried in the mud and a small flattened lamina spread out in the water, strikingly resembles in its structure the huge stem of *Nematophycus*, as Dawson's *Prototaxites* has been re-named by the speaker.†

The so-called Algæ from the Coal Measures do not prove satisfactory on examination. Many plants have suffered decay before or after being covered by deposits; and, as Mr. Dyer showed, the alleged Algæ from Solenhofen were composed of flattened and decayed specimens of coniferous plants, so the greater number of the alleged species will be found on careful examination to have a similar origin. Undoubted Algæ occur in Cretaceous and Tertiary strata; but even mere markings destitute of structure are sometimes of value for stratigraphical purposes as marking particular horizons.

As Algæ possess chlorophyll, they have the power of living on inorganic material, and should, from this point of view, be placed below Fungi, which live on organic matter. They are sometimes unicellular, the lowest groups multiplying simply by division; and no group of plants and few groups of animals form such important rock-masses as do some of these minute Algæ. Whilst other cellular plants decompose speedily after death, the *Diatomaceæ*, as they secrete an almost indestructible siliceous skeleton, are beautifully preserved. From their abundance in water and their minute size they may find their way into the material being prepared by the microscopist, and the speaker believed this was the explanation of the supposed diatoms found by Count Castrocane in the Coal Measures. None had yet been detected with certainty below the Tertiary.

---

* Professor Sollas's recent paper, 'Proc. Roy. Dublin Soc.,' n.s., v. (1886-7), 355, seems to show the purely mineral nature of this structure. It is found ramifying across the bedding-planes of the rock.—ED.

† In his recent work, 'The Geological History of Plants,' Sir J. W. Dawson practically abandons his original opinion.—W. C.

The rock formed of their accumulated skeletons is used as a polishing powder and as an absorbent of nitro-glycerine in the manufacture of dynamite. A mass of three or four cubic feet, from Victoria, recently placed in the outer gallery of the Department, and consisting, like that described from Scottish peat by Greville and Gregory, entirely of recent species, has been calculated to contain a thousand billion individuals. On the other hand, the larger Algæ like the *Laminarieæ*—some of which, such as those described by Sir J. D. Hooker from the South Pacific, are among the largest of known plants- -being composed entirely of easily perishable cells, are unrepresented in a fossil state, the alleged Cretaceous forms being imperfectly preserved coniferous plants.

Of other groups the *Desmideæ* may possibly be represented by the genus *Xanthidium*, found in the flints of our Chalk and figured by Mantell; but this is doubtful.

The President, in proposing a vote of thanks to Mr. Carruthers, said that he esteemed it a privilege to act as the interpreter of the gratitude of the Members present to him, both for receiving them and for giving them so admirable an address. Mr. Carruthers had been formerly their President, had given them many demonstrations, and was always so willing to impart information that, as palæontologists were reproached for neglecting plants, he hoped this might be the first of a series dealing with the several classes of the vegetable kingdom. Dr. Dukinfield Scott, in seconding the proposal, which was heartily received, said that as a student of Algæ he had been much gratified at the exposition of what was known of the fossil remains of a group of which there was so exasperating a want of material.

EXCURSION TO WIMBLEDON AND PUTNEY, SATURDAY AFTERNOON, MAY 5TH, 1888.

Directors: O. M. PROUSE, F.G.S., and W. TOPLEY, F.R.S., F.G.S.

(*Report by* W. TOPLEY.)

The party assembled at Wimbledon Station, and proceeded along the unfinished railway, through Wimbledon Park, to Putney, where the railway crosses the Thames by a new bridge just east of The Cedars to join the District Railway.

An engine and trucks had been kindly provided for the party by Messrs. Lucas and Aird, the Contractors.

Just east of Wimbledon Station was a fine exposure of London Clay with lines of Septaria dipping a few degrees east of north. Here Mr. W. H. Hudleston, F.R.S., gave a description of the mode of formation of ironstone and Septarian nodules in clays. Mr. Prouse described the way in which the American "steam navvy" excavated the clay. Good sections of the London Clay had formerly been exposed where the line crosses the Wimbledon Road, near Elm Lodge, and also in the deep cutting, now in part a tunnel, under the Kingston Road. In these places, too, the dip was at a low angle to the north or a little east of north; there were also good layers of Septaria and lines of Selenite. The piles of the bridge over the Thames were in London Clay, and from here some fossils had been obtained, including Nautilus and Crinoid stems.

On the flat land north-east of the lake in Wimbledon Park some indications of gravel had been observed; and on this occasion Mr. Clement Reid, F.G.S., had brought with him the hand-boring tools recently adopted by the Geological Survey from the Geological Survey of Belgium. A few trial-holes showed that there was a covering of gravel over this flat land not yet recorded on the maps.

The most important beds of drift along the line, however, are those just north of the Kingston Road. Here thick beds of sand and gravel were seen banked against the old river-cliff of London Clay. The gravel became finer and more mixed with sand towards the river.

Tea was kindly provided by Mr. Prouse at his office; after which the party walked to the river and inspected the bridge.

EXCURSION TO CHARNWOOD FOREST.

MONDAY AND TUESDAY, MAY 21ST AND 22ND, 1888.

Directors: Rev. E. HILL, M.A., F.G.S., and J. D. PAUL, F.G.S.

(*Report by* MR. PAUL.)

After a lapse of thirteen years the Association decided to revisit Charnwood Forest for its Whitsuntide Excursion. The programme was arranged with the idea of showing to the Members the advances which had been made since their last visit in the solution of the geological problems suggested by the district. The first step in working out its geology was made by Sedgwick in 1833, when he correctly laid down the position of the anticlinal, and the Rev. W. H. Coleman* subsequently did a great deal of excellent field-work. Beete Jukes also, who was employed for a year or two in the neighbourhood, published in 1842 his Memoir, containing the earliest geological map and survey of the Forest. His explanation of the geology of the district was the result of much accurate observation, combined with a thorough knowledge of the science as it was then generally understood; but it was vitiated by the mistake which led him to set down as igneous, the porphyries whose outcrops occupy such a large area to the north-west. This error remained uncorrected till Messrs. Hill and Bonney read their first paper before the Geological Society in 1877, on the "Pre-Carboniferous Rocks of Charnwood Forest." The advances which had been made in petrology and the use of the microscope in the examination of rocks enabled them to demonstrate that the Forest contained an important series of altered volcanic rocks, and to distinguish these from the intrusive igneous syenites, granites, and basalts.

The first day's Excursion of the Association was to the southern end of the anticlinal at Holgate Hill, in Bradgate Park. The banded slates forming the face of the cliff at this locality were carefully examined, and the stripe, showing a dip to south-west, was noted, whilst about 200 yards further to the east a pebble-bed dipped in the opposite direction. Walking along the beds in descending order, the volcanic character of the agglomerates was well shown in a pile of rocks near Old John, where angular pieces of slate, several feet long, were seen imbedded in an ashy matrix. The position of these agglomerates and their importance in the Charnwood Series and the direction of their outcrop were carefully considered. The Stable Quarry and other points of geological interest in the Park were all examined. On their way home the Members visited the Sheet Hedges Quarry, and took specimens of the syenite, which presents several interesting peculiarities. A full description of it will be found at page 270 of Mr. Teall's 'British Petrography.' The attention of the Members was called to the excellent sections of Upper Keuper in the cuttings of the quarry railway. The horizontal beds of Red Marl and Grey Sandstone, containing pseudomorphs of salt crystals, lying upon the uneven surface of the syenite, afforded a striking evidence of the quiet deposition of these beds upon the floor of the Triassic sea.

---

* The same geologist to whom Professor A. H. Green has dedicated his admirable work on geology.

The next day's Excursion commenced at Mount Sorrel, where a large quarry has been worked for many years in the mass of hornblendic granite, which occupies at the surface an area of one or two square miles on the eastern margin of the Forest. It was pointed out that Charnwood presented in miniature all the features of a mountain chain. Its points of elevation are near and parallel to the anticlinal, and it is bounded on one side by one immense fault, and probably by another on the other side. The Rev. O. Fisher* has shown that in such chains the outbursts of igneous rock are not usually found along the anticlinal, but at some distance on either side, towards the roots of the hills, and this is well illustrated here by the positions of the great masses of igneous rock at Mount Sorrel and at Groby. The variety in the colour of the rock in different parts of the quarry was observed, and specimens of grey, salmon-colour, and red were easily obtained. The hornblende and the crystals of quartz and pinkish felspar were readily recognized by the naked eye, but the specks of black mica and magnetite were mostly too minute to be seen without a glass. Both felspars are a good deal decomposed. The hornblende has suffered in the same way, and the joints of the rock are filled with a bright yellowish-green epidote. Here and there are nodules of pyrites and sulphate of copper, with occasional traces of molybdenite. The black, sharply-defined patches which were seen on the fractured surfaces of the granite are probably included fragments of some other rock caught up in the granite whilst it was in a molten state.

---

* 'Trans. Camb. Phil. Society,' xii, Part ii, 1877.

The rock at Mount Sorrel, like several other masses on the Forest, marks a line of weakness, along which more than one extrusion has occurred at different times. A dyke of dolerite two or three yards wide runs through the quarry, and a few years since another of felstone could be seen, but this, the foreman said, had all been quarried away. The Members walked round by the northern end of the quarry to examine some peculiarities in the shape and surface of the rock which, it had been suggested, were the result of ice-action. Professor Blake said that he had examined this part of the quarry with the late Professor Carvell Lewis, and they both came to the conclusion that there was no evidence of the action of ice, and this was the general opinion of those present.

The route was then followed over the granite boss of Kinchley Hill to the outcrops of diorite, which occur both outside and inside Brazil Wood. The Members spent a considerable time in the wood examining the contact which is visible here between the igneous and sedimentary rocks. Mr. Allport * first pointed out that the micaceous schist of the Brazil Wood is the slate of the Upper Forest bed altered by the intrusion of veins of granite. Approaching within a few yards of each other we have the mass of granite lying at the northern end of the wood, and at the other end a mass of ordinary sedimentary slate, and between these two comes a patch of contorted micaceous schist, in which may be seen the veins of the intruding granite which have caused the alteration of the slate into the schist. The contact is often sufficiently sharp for the granite and the schist to be well seen in a microscopic section. Half-an-hour's walk across the fields brought the Members to the deep quarries in the Workable Slates in Swithland Wood. They were quarried here years ago for roofing purposes, but were superseded by the thinner though softer Welsh slates. Some of these Swithland slates were not long since taken from

---

* 'Geol. Mag.,' Nov., 1879, 481.

the roof of Rothley Temple, where they had been exposed to the weather for 600 years, and they were found to be as sharp as the day they were taken from the quarry. The Excursion concluded with an examination of the banded slates and pebble-beds of the hanging rocks in Beaumanor Park. After a careful inspection of the Ring Pit, the Members were of opinion that the circular workings seen there showed no evidence of organic origin. A few of the more active Members ascended Beacon Hill, and had a splendid view of the surrounding country.

The concluding Excursion, under the direction of the Rev. E. Hill, was devoted to the examination of the lower and mainly volcanic beds of the Charnwood Series. They are admirably shown in the section over which the Members worked, from the Forest Rock Inn to Blackbrook. The section shows the series in descending order, commencing with the porphyries, passing over the agglomerates, and finally reaching the lowest beds of all, the quartzites of Blackbrook and Ives Head. The thickness of these beds, with the addition of the Forest Gate Beds and the Workable Slates, according to Messrs. Hill and Bonney, is probably not less than 7,500 feet. The quarry close to the Forest Rock Inn showed the slate altered to a hornstone and dipping towards the south-west. Returning then to the road, the party proceeded first along the road leading to the Monastery and then along the fields parallel to it. Mr. Hill pointed out the cliffs composed of a thick bed of breccia with large included pieces of slate and other rocks embedded in an ashy matrix. Beyond were masses of agglomerates and coarse ash beds, and last of all were seen the banded grits or quartzites. The Members made their way back to the cross roads by the Monastery, High Sharpley, and Peldar Tor. The Sharpley rock possesses considerable interest, as a rock which Professor Bonney thinks closely resembles it has been found in a boring at a depth of 760 feet at Orton, near Kettering, 20 miles south of the Forest. During their stay in Leicester the Members did not confine their attention to the geology of the neighbourhood. Those who came down from town on Saturday afternoon spent a most agreeable two hours in the evening in looking over the Museum, which since the last visit of the Association has been so far remodelled by the Curator, Mr. Montague Browne, F.Z.S., as to take a very high rank amongst provincial museums.

The artistic setting up of the animals in the vertebrate room was specially admired. The specimens of Saurians from the Lias at Barrow-on-Soar, in the geological room, of course received much attention from the Members. A cordial vote of thanks was given to the Curator for his kindness in conducting the Members round the Museum and for the trouble he had taken. The early hours of Monday, previous to the arrival of the Members who came down from town, were spent in examining the abundant Roman, Norman, and mediæval antiquities of Leicester.

REFERENCES.

Geological Survey Map, Sheet 63, N.E. and N.W.

Horizontal Sections 46, 48, and 52.

HILL, REV. E., and BONNEY, REV. T. G.—"The Pre-Carboniferous Rocks of Charnwood Forest," *Quart. Journ. Geol. Soc.*, Vol. xxxiii, 1877, p. 754; xxxiv, 1878, p. 199; xxxvi, 1880, p. 337.

BONNEY, PROF. T. G.—"On the Archæan Rocks of Great Britain," *Rep. Brit. Assoc.*, Montreal Meeting, 1884, p. 529 (Charnwood Forest, p. 536).

BERRY, E. E.—"Analyses of Five Rocks from the Charnwood Forest District," *Quart. Journ. Geol. Soc.*, Vol. xxxviii, 1882, p. 197.

HARRISON, J. W.—"A Sketch of the Geology of Leicestershire." (From *White's Gazetteer.*) Simpkin, Marshall & Co., 1877. Large edition, with 12 photographs.

——— "Geology of the Counties of England." 1882 (Leicestershire, p. 151).

——— "On the Geology of Leicestershire," *Proc. Geol. Assoc.*, Vol. v, 1877, p. 126.

——— "Garnets in Charnwood Rocks." *Midland Naturalist*, vol. ii, p. 77.

ALLPORT, S., and HARRISON, W. J.—"Rocks of Brazil Wood," *Midland Naturalist*, Vol. ii, p. 243.

HUDLESTON, W. H.—"Report of Excursion to Charnwood Forest," *Proc. Geol. Assoc.*, Vol. iv, 1875, p. 307.

NOTES ON THE MICROSCOPIC CHARACTER OF SOME SPECIMENS OF ROCKS COLLECTED DURING THE EXCURSION TO CHARNWOOD FOREST.

By MAJOR-GENERAL C. A. McMAHON, F.G.S.

On the occasion of the recent Excursion of the Geologists' Association to the Charnwood Forest under the guidance of Messrs. Hill and Paul, I secured some good specimens of the interesting rocks pointed out to us, and subsequently studied thin slices of them under the microscope for my own amusement and instruction. As other Members of the Association were equally diligent in collecting typical samples, a few notes on such of the Charnwood Forest Beds as we were able to examine may be of some interest to them.

In the following remarks I have referred to the leading authorities regarding these rocks, and it will be seen that the conclusions I have arrived at are, in nearly all cases, identical with those expressed by them. The exceptions, in which I have formed a somewhat different view, refer to rocks of very doubtful character, in respect of which an independent opinion may not be without some value. In highly altered rocks of this class, much, of course, depends on the condition of the specimens examined. A single sample of a comparatively unaltered specimen may give better results than a dozen others in which decomposition has advanced to a greater extent. It is on this ground only that I venture to offer the conclusions at which I have arrived for the consideration of fellow students.

Syenite from Sheet Hedges Quarry, near Groby Pool.

The Groby syenite has been described by Messrs. Hill and Bonney in the 'Quarterly Journal of the Geological Society,' Vol. xxxiv, 212, 214, and by J. J. Harris Teall in his 'British Petrography,' p. 270—a most valuable work which should be in the possession of all students of Petrology.

The thin slice taken from my hand specimen of this rock contains felspar (much of which is visibly triclinic), free quartz, hornblende, apatite, epidote, chlorite, viridite, and magnetite or ilmenite.

Owing to the prominent part plagioclase takes in its composition this rock is not a true syenite. In addition to the above minerals, Mr. Teall found unaltered augite in most of the slides examined by him.

The most characteristic feature in this interesting rock is the micro-pegmatic combination of much of the quartz and "orthoclase" (Teall) contained in it, considerable portions of my slice having the appearance of graphic granite. This orthoclase is quite structureless and does not exhibit cleavage, twinning, or crystallographic form, and resembles the felsitic base of a felsite.

The plagioclase has suffered considerable alteration, having been largely converted into kaolin, chlorite, and in some cases into a silvery mica. The inner portions of the plagioclase have suffered more than the external, and the plagioclase more than the orthoclase. The reason for this is probably that the more basic felspar separated out from the magma in the first instance and formed the kernels of the plagioclase crystals; the peripheral portions of the latter formed next, and last of all the residuum of orthoclase and quartz.

The felspar is of two colours, pink and green. The former is, I think, the natural colour of the mineral, the green tint being due to the formation of chlorite in the substance of the felspar. As far as I can judge, the whole of the plagioclase is not of green colour; whilst, on the other hand, some of the green felspar undoubtedly exhibits the micro-pegmatic structure. Speaking broadly, chlorite has been formed in the substance of the plagioclase to a much larger extent than in the orthoclase, and this fact has given rise to the impression that the whole of the pink felspar is orthoclase, and the whole of the green felspar plagioclase.

Water appears to have been the agent that produced the changes set up in this rock. The abundance of epidote (a mineral commonly met with in amygdules) points in that direction, whilst the production of chlorite in minute granular patches in the plagioclase seems to tell the same tale. The conversion of felspar into chlorite, according to Bischof,* may be effected by the percolation of water containing bicarbonate of magnesia and some protocarbonate of iron. The former would, Bischof states, decompose the alkaline silicates and the latter the silicate of alumina; part of the silica would be removed and part utilized in the formation of the silicates of magnesia and iron required for the chlorite. As the augite, or hornblende, contained in the original rock would supply the magnesia, and the magnetite, or hornblende, the iron, all that seems required to effect the changes observed in the syenite is the percolation of water charged with carbon dioxide.

The free quartz contains liquid cavities with moving bubbles.

Quartz-Diorite from Brazil Wood.

This is a fine-grained holocrystalline rock, composed of plagioclase, hornblende, and quartz. It also contains apatite, mica (red in transmitted light), sphene, magnetite, and a chloritic-micaceous mineral colourless to pale green in transmitted light. The cleavage of the last-named mineral is very imperfectly developed, and its double refraction is extremely feeble, but, nevertheless, it appears to be more of a mica than a chlorite. It is evidently a secondary product.

---

* 'Chemical and Physical Geology,' by Gustav Bischof, translated by Paul, Vol. ii, 174.

The felspar is not much decayed. The hornblende is strongly dichroic, and exhibits good idiomorphic outlines and characteristic cleavage. Twinning is very common in it; traces of polysynthetic twinning are not unfrequent, and the slice contains one good example of penetration twins.

Liquid cavities with fixed and moveable bubbles and gas inclusions are common in the quartz. The magnetite has, here and there, been decomposed into the red oxide of iron.

This appears to be the rock described by Professor Bonney, at Vol. xxxiv, p. 224, 'Q. J. G. S.,' though his specimens do not seem to have been collected in quite the same locality as my own.

Mount Sorrel Granite.

This rock has been described by Professor Bonney at p. 219 'Q. J. G. S.,' Vol. xxxiv, and an account of it will also be found at p. 321 of Teall's 'British Petrography.' The microscopic character of a glass that resulted from a fusion of a considerable quantity of this rock is described by Dr. Sorby in the 'Proc. Geol. and Poly. Soc. West Yorks.,' Vol. iv, p. 301.

The slice of my hand-specimen exhibits a holocrystalline mixture of felspar, quartz, biotite, hornblende, apatite, and magnetite.

The felspar is of two kinds, orthoclase and plagioclase, the latter being as abundant as the former. Biotite predominates considerably over the hornblende. In addition to the ordinary biotite, which is of reddish brown colour in transmitted light, there is a green mica which is very often interwoven with the former in a way to suggest the intergrowth of two distinct species. The green variety, however, is, I think, simply a product of decay. The process seems to me to have been as follows: the iron appears to have been "leeched" (to use an expressive Americanism) out of some biotite laminæ, and portions of laminæ, and deposited in lines of basal cleavage in the form of ilmenite very much in the way that iron is deposited in cracks in olivine in the course of the conversion of the latter mineral into serpentine. Subsequently the iron itself was removed from the cleavage cracks and a white opaque substance left behind that is indistinguishable from leucoxene.

In ordinary transmitted light the hornblende does not materially differ in colour from the green variety of mica.

My slice contains several good crystals of zircon. As pointed out by Dr. Sorby, the quartz is rich in liquid-cavities, many of which contain moving bubbles.

Basaltic Dyke in the Mount Sorrel Granite.

When the Members of the Association visited the pit, recently quarried and comparatively undecomposed specimens of this rock were available. It is a fine-grained but distinctly crystalline rock, the long prisms of felspar being visible with an ordinary pocket-lens.

A description of the microscopic character of this basalt will be found at p. 222 of Messrs. Hill and Bonney's paper ('Q. J. G. S.,' Vol. xxxiv), and a longer description of a similar rock in the Groby pit at p. 220.

My specimen consists of a mixture of plagioclase, augite, and magnetite as original constituents, with hornblende, sphene, serpentinous viridite, red ferrite, granular calcite, and quartz as secondary products.

The triclinic felspar is in lath-shaped prisms; but it is too much decomposed for the determination of its species. It was one of the first of the minerals to crystallize out of the magma.

Augite is abundant, and much of it is in excellent preservation.

The hornblende seen in the slice is apparently a product of the alteration of augite. In some cases the external portions of prisms are composed of hornblende and the kernels of unaltered augite.

Sphene is abundant, and is evidently an alteration product. The free quartz present in this rock is undoubtedly a secondary mineral, and granules of it are always associated with calcite, or viridite, or both. Liquid cavities with moving bubbles abound in these granules, and this fact, taken in connection with the secondary origin of the quartz, seems to indicate that the decay of the rock, and the mineral changes set up in it have been due to hydro-thermal action.

Some of the serpentinous viridite plays the *rôle* of a glassy base, and here and there the appearances are such as to suggest that an uncrystallized residuum was originally present in the unaltered rock. In the basalts of Bombay, which I described in a paper published in the 'Records of the Geol. Surv. of India' (Vol. xvi, 42), the alteration of the brown glassy magma into a green amorphous substance may be distinctly traced in all stages of conversion, and it is there seen to be due to the agency of water. Professor Bonney, I observe, also states that " the finer variety " of the Mount Sorrel Rock " shows the remains of a glassy base." In view of this fact, I have applied the term "basaltic" to the dyke seen in the Mount Sorrel hornblendic granite, for, according to Professor Judd, the distinction between a basalt and a dolerite consists in the presence of a glassy base between the crystals of the former rock ('Q. J. G. S.,' xli, 361). As the existence of a glassy base indicates comparatively rapid cooling at, or near, the earth's surface, this distinction is an important one. It would indicate, for instance, a wide difference in age between the Mount Sorrel granite and the basalt of the dyke. The granite consolidated under plutonic conditions, but it must have been brought by the slow erosion of superincumbent masses of rock comparatively near to the surface before the basaltic eruption took place. The presence of liquid cavities with moving bubbles in the secondary quartz of this basalt does not, I should perhaps explain, necessarily denote plutonic conditions. I have observed such inclusions in the quartz present in Aden lavas, and in secondary calcite and epidote in amygdules from other localities, for none of which can a plutonic origin be assigned. Liquid-cavities are also abundantly present in the rhyolitic rocks described further on.

The Micaceous Rock of Brazil Wood.

This rock has been called a " gneiss " and a " micaceous schist " by some observers, but as it is not foliated or schistose in structure, neither term seems strictly applicable.

The microscopic character of specimens of this rock has been described by Professor Bonney (' Q. J. G. S.,' Vol. xxxiii, 783), and by Mr. Allport (' Geol. Mag.,' 1879, p. 483), and a chemical analysis of it is given in Messrs. Hill and Bonney's second paper on the "Charnwood Forest Rocks" ('Q. J. G. S.,' xxxiv, 224). The rock is also noticed at p. 388 of Teall's 'British Petrography.'

Messrs. Hill and Bonney considered that the rock was originally "a finely-levigated mud" that had been intensely metamorphosed. Mr. Allport's view seems substantially the same, with this difference, that whereas Messrs. Hill and Bonney did not indicate the probable cause of metamorphism, Mr. Allport asserts that it has been produced by contact metamorphism and states that the "Charnwood Rock is singularly like some of the Devonian slates near their junction with the Land's End granite."

This rock deserves the attentive study of students, and I think it may be accepted as a good example of intense contact metamorphism acting on a consolidated mud or a clay-slate. Time was when some geologists believed that slates could be converted into granite. The Brazil Wood rock has been intensely metamorphosed, but a cursory examination will show that though the mica which forms a large portion of its substance orients in all directions, the rock does not bear the most remote resemblance to a granite or any other igneous rock of that class. Another point to be noted is that though the chemical analysis of this rock referred to above yielded 21·87 per cent. of oxide of aluminium, 4·66 per cent. of soda and potash, and 2·13 per cent. of lime, in addition to an ample supply of silica, the slice examined by me does not contain a single crystal of felspar, big or small. The fact is "the process of contact-metamorphism seems very unfavourable to the formation of a felspar" (Bonney, 'Q. J. G. S.,' xliv, 18), a remark I can confirm from my own experience.

The Brazil Wood Rock consists of a colourless mica, an olive-green mica (I speak of their colours as seen in a thin slice by transmitted light), grains of quartz, and very numerous specks of magnetite and ferrite. Some of the mica is red, the red colour being probably due to staining with iron oxide. A tendency on the part of the reddish mica to flow in approximately parallel directions may be distinctly observed.

In my specimen the quartz grains contain liquid cavities with moving bubbles distributed promiscuously throughout them, a fact which appears to indicate that at the time of the granitic intrusion the rock either contained a considerable amount of water or was permeated by heated water emanating from the rising granite. The formation of liquid-cavities in quartz, however, is not an invariable result of contact-action. On the contrary, in many cases the heat of the injected rock expels the water contained in the pre-existing liquid-cavities in quartz grains of clastic origin. In a paper on "Some Dalhousie Rocks" ('Records, Geol. Surv. India,' xvi, 141) I have quoted observations by Professor A. Geikie ('Nature,' December 7th, 1882), and Dr. Sorby ('Q. J. G. S.,' xxxvi, 82) on the latter aspect of contact-metamorphism.

The metamorphic changes produced by contact with eruptive masses appear to arise in part from the effect of heat on the strata acted on—an effect powerfully aided by the water contained in the latter—and in part from the injection of heated water charged with mineral matter from the eruptive mass. In connection with the latter aspect of the case, Allport's paper on the "Metamorphic Rocks surrounding the Land's End Mass of Granite" ('Q. J. G. S.,' xxxii, 407) and Teall's 'British Petrography,' p. 221, should be studied.

The mineralogical changes produced in Silurian slates by contact with Himalayan gneissose-granite, described by me in the paper alluded to above, are nearly identical with those exhibited by the Brazil Wood Rock, the slates in contact with the granite having been converted into a mixture of two kinds of mica, quartz, magnetite, and ferrite. This being so, I see no reason to doubt that the Brazil Wood Rock is, as alleged by Allport, the product of contact-metamorphism acting on a clay-slate.

Indurated Gritty Argillaceous Rock from Quarry close to the Forest Rock Inn.

This was at the time of our visit to the quarry called an indurated ashy slate, and the induration was supposed to be due to an unseen and hypothetic igneous rock.*

Small splinters of the rock fuse very readily under the blowpipe, and when breathed upon the hand-specimen has a strong earthy smell. When examined with a pocket-lens the rock is seen to be micro-conglomeratic, the included fragments being very sparsely distributed through it.

---

* The Rev. E. Hill, speaking for himself, writes, "I should be very sorry to have said such a thing."—Ed.

Under the microscope the matrix presents the normal appearance of a mudstone, that is to say, of a clay-slate minus all trace of lamination or cleavage. In this matrix angular to subangular micro-grains of quartz are distributed with some larger silicious fragments, in some of which a micaceous chlorite is rather abundant. Grains of magnetite are to be seen here and there, and some of the magnetite has been altered into the red oxide of iron. The slice is also dotted with specks of an opaque material, white in reflected light, which may represent grains of titaniferous iron converted into a substance resembling leucoxene.

The quartz grains contain numerous liquid cavities, with moveable bubbles. The larger silicious fragments have nothing distinctive about them, whilst the matrix does not contain any evidence of "ashy" origin.

This appears to be an indurated mud of gritty texture in which cleavage has not been superinduced. I cannot discover in it any evidence of contact-metamorphism.*

Ash of different degrees of fineness from Altar Stones.

These are typical specimens of ash-beds, and should be carefully studied as such by the petrographical student. I have examined three slices of fine-grained ash. They consist of fragments of acid lavas, fragments of felspar crystals, and fragments of quartz. In one specimen the quartz fragments are numerous, in the second they are sparse, and in the third absent. In the latter, fragments of felspar crystals, most of which exhibit the polysynthetic twinning of plagioclase, are very abundant, whilst in the former they are small, comparatively scanty, and few of them exhibit multiple twinning. Liquid cavities with moveable bubbles abound in the quartz. The fragments of this mineral are not rounded, and afford no evidence of having been water-borne. The appearance of one of the slices, however (that in which there are no fragments of quartz), shows that the lapilli were either deposited in water and settled down along with a finely-triturated mud, or else that they fell along with an extremely fine dust that was subsequently subjected to the action of water. A careful examination shows an important difference between this ash and the Peldar Tor Rock. The ash under description not only contains numerous lapilli, differing from one another in appearance, that show at once its pyroclastic origin, but the fragments of felspar crystals imbedded in the insterstitial mud, however small in size, all afford evidence of fragmental origin. This cannot be affirmed of my Peldar Tor specimens.

---

* Since writing the above I find, on again referring to Messrs. Hill and Bonney's paper, that specimens from this quarry have been described by Professor Bonney ('Q. J. G. S.,' xxxiii, 773; xxxiv, 202). Our specimens doubtless came from different horizons in the quarry, as Professor Bonney's contained fragments of felspar. The general conclusion, however, at which he arrived agrees with mine, for he sums up his remarks by saying "the rock is probably not pyroclastic."

I have not discovered any lapilli of basic lava, and the slices do not contain any augite or hornblende. Grains of magnetite and ilmenite are present; much of the former has been converted into the red oxide of iron, whilst the latter is surrounded with a border of leucoxene. One of the slices contains some shapeless grains of what appears to be sphene—probably a pseudomorph after ilmenite. It possesses the appearance and high double refraction of sphene, and one of the minerals is twinned.

The fragments of lava and of felspar, and the ground-mass, are all highly altered by the action of water. Some secondary quartz has been introduced, and epidote and chlorite have been formed in some abundance. Both epidote and chlorite stop cracks and cavities, and have been formed in, and apparently at the expense of, felspar crystals, and penetrate the substance of the lava fragments.

The slice from which fragments of quartz are absent contains numerous crystals of apatite.

Purple rhyolite fragments in the volcanic agglomerates of Altar Stones.

Mr. Hill was good enough to point out to me in the field a typical specimen of this rock in a very coarse-grained agglomerate, and I secured specimens of it for microscopical examination. The interest specially attaching to this rock is, I understand, that fragments of a similar rock are found in the agglomerates of the Wrekin, and an argument in favour of the correlation of the Wrekin and Charnwood Forest Beds is based on this fact. In microscopic characters the sample I examined agreed more closely with that given by Professor Bonney at pp. 201, 202, 'Q. J. G. S.,' Vol. xxxiv, than any of those described at p. 207.

This rock appears to be something between a quartz-porphyry and a quartz-trachyte. Viewed macroscopically it is of grey colour slightly tinged with purple. It consists of a compact base in which blebs of quartz and very minute, generally ill-defined, crystals of felspar are dotted about so as to give the rock a speckled appearance.

Under the microscope the porphyritic crystals are seen to consist of orthoclase, plagioclase, and quartz. The ground-mass contains some grains of magnetite and of red oxide of iron, the latter having also stained some of the felspars to a considerable extent. To the presence of this red oxide of iron the purplish tint of the rock is doubtless due. The ground-mass is also filled to a considerable extent with what appear to be ferriferous products in a granular condition. Some of these are opaque in transmitted and white in reflected light, and resemble a decomposition product of ilmenite known as leucoxene; others resemble limonite.

The ground-mass appears to be made up of ferriferous decomposition products disseminated through a base composed of imperfectly individualized quartz and felspar which breaks up under crossed nicols into flocculent specks, possessing feeble double refraction, that stand out from a dark background. The ground-mass under crossed nicols exactly resembles the base of many quartz-porphyries.

The felspar crystals have been to some extent decomposed, and here and there epidote and chlorite have been formed in them.

The quartz crystals have been corroded, rounded, eaten into, and invaded by tongues of the base, after the manner of the quartzes of quartz-porphyries, and they abound in liquid-cavities with fixed and moving bubbles.

The base of the rock resembles as closely as possible the majority of the microscopic fragments contained in the fine-grained ash-beds already described; and as the quartzes of the rhyolite under examination contain numerous fluid-lacunæ, we need not look further than the parent-rock from which the fragment found in the coarse agglomerate was derived, for the rock that supplied the small fragments of quartz and felspar contained in the fine-grained ash-beds. In other words, the quartz and felspar fragments contained in the fine-grained ashes, like the majority of the lapilli found therein, were probably derived from a porphyritic rhyolitic rock, and not necessarily, as the abundance of the fluid lacunæ might at first sight suggest, from a granite.

The Sharpley Rock.

Mr. Hill was good enough to lead us to a good outcrop of this rock, and I secured a typical specimen of it in very fair preservation.

This rock is alluded to at p. 777 of Messrs. Hill and Bonney's first paper ('Q. J. G. S.,' xxxiii), and the opinion was recorded that it is the equivalent of the Peldar Tor Rock. I do not think the Sharpley Rock is expressly alluded to in the second paper in Vol. xxxiv. Both the Sharpley and the Peldar Tor Rock were considered very doubtful rocks, but the authors inclined hesitatingly to regard them as of fragmental origin ('Q. J. G. S.,' xxxiii, 776; xxxiv, 210).

Whether I have been specially fortunate in securing a well-preserved specimen which gives exceptionally good results, or whether I have been specially rash in forming a conclusion on the examination of a single specimen, I cannot say, but, any way, I incline strongly to the opinion that the sample I secured is that of a rock in no essential respect different from that last described. I have formed my opinion principally on the following grounds:—The ground-mass of my slice is a perfectly homogeneous felsite. No trace of an original fragmental origin is to be detected in it. The felspar crystals (both plagioclase and orthoclase are present) are in shapes appropriate to a rhyolitic rock and are not in the angular fragmental forms commonly seen in an ash. One long prism of felspar has been broken in two and the fragments floated apart in the way sometimes seen in igneous rocks, whilst the quartz grains have been eroded and contain the tongues and inclusions of the ground-mass so commonly seen in quartz-porphyries and rocks of that type. There is no trace of a break between these tongues in the quartz and the adjoining ground-mass, and I cannot, even with high powers, distinguish any difference of structure between them. The ground-mass has a certain individuality of its own, and this is seen in the tongues and inclusions. The latter, it may be as well to note in passing, are too sharp and well defined to be mistaken for overlappings of the base.

As in the case of the porphyritic rhyolite last described, the quartz grains abound in liquid cavities with moving bubbles.

The Peldar Tor Rock.

This rock is described at pp. 776, Vol. xxxiii, and 210, Vol. xxxiv, 'Q. J. G. S.'

I secured two specimens, one being in fairly good preservation, and not nearly so much decomposed as the majority of the fragments that I examined in the course of my walk.

The reasons that I have given for concluding that the Sharpley outcrop is a porphyritic lava and not a fragmental rock apply almost equally well to the Peldar Tor samples examined by me. The ground-mass is homogeneous in structure, and exhibits no trace, under the microscope, of clastic or pyroclastic origin. The rock has undoubtedly suffered considerably from the permeation of water, but I do not think the alteration thereby set up has in the two specimens examined by me entirely obliterated its original structure. Besides the porphyritic crystals, many of which are distinctly idiomorphic, the base of my best specimen contains very numerous micro-prisms of felspar in the slender elongated forms, and oriented in the manner, commonly seen in the later "generation" of felspars in typical lavas. Many of these are visibly triclinic. I see no reason to suppose that these minute idiomorphic prisms of triclinic felspar are of pyroclastic origin, as remarked above under the head of Ash, and there is nothing about them to suggest that they are of secondary origin. On the contrary, they have suffered equally with their larger brethren from the decomposing aqueous agencies to which the presence of secondary epidote and chlorite in the rock may be attributed.

The porphyritic quartzes in the rock above described contain numerous liquid cavities.

The presence of liquid-cavities in the quartz of such rocks as the porphyritic rhyolite, the volcanic origin of which has never been doubted, is an interesting feature, and it shows that we might err seriously were we to argue from their presence that the quartz fragments contained in clastic or pyroclastic rocks were invariably derived from a granite. Conversely the presence of fluid-lacunæ in the quartzes of the Peldar Tor Rock does not prove it to be of clastic or pyroclastic origin.*

---

* Professor Bonney and the Rev. E. Hill are engaged in a further study of this region, and of these Sharpley and Peldar Tor rocks in particular.

EXCURSION TO LAINDON (OR LANGDON) HILLS, ESSEX.

SATURDAY, JUNE 9TH, 1888.

(In conjunction with the Essex Field Club.)

Directors: W. WHITAKER, F.R.S., and WALTER CROUCH, F.Z.S.

(*Report by* T. V. HOLMES, F.G.S.)

The opening, on June 1st, of the new line of railway from Barking to Pitsea having made Laindon Hills much more easily accessible than they were when the old line to Southend, *viâ* Tilbury, was alone available, this Excursion of the above societies was very numerously attended. About ninety Members were present in spite of the unfavourable weather, which, in addition to being showery, gave little promise of the extensive panoramic views mentioned in the programme, which result from the position of Laindon Hills as an outlying patch of Bagshot Beds in the middle of a London Clay district.

At Laindon Hills Railway Station the attention of the party was directed to the deep boring which was being made for a well in order to obtain a supply of water from some water-bearing bed below the impervious London Clay, which there forms the surface. Mr. Legrand, the gentleman superintending the execution of this work, was purposely present at the station, and kindly gave much information about this boring. From him we learned that the depth then reached was 444ft., and from his remarks, and from samples of the material brought up from various depths, we ascertained that the uppermost 342ft. of the boring were in London Clay. Immediately below the London Clay were:—

Light-coloured sand with shells ...	1ft.
Pebbles	2ft.
Light-coloured sand with shells ...	21ft.

The beds below this depth of 366ft. were all more or less sandy. Mr. Legrand also stated that the septarian nodules found in

London Clay were the only sources of difficulty to the borer in that formation.

Leaving the Railway-Station, the party turned southward and ascended Laindon Hills, whose summit is about a mile away. On reaching the top it went for a distance of some two or three hundred yards along the road, which ranges in an easterly direction towards Dry Street and Vange, to a spot where on the northern side there is a pit showing 12ft. or more of Bagshot Sand below three or four feet of loamy material. Here a heavy shower of rain fell, and Mr. Whitaker, looking down on the umbrellas of his attentive audience, discoursed on the geology of Laindon Hills and the district surrounding them. At the Railway Station (he said) they had learnt that the thickness of the London Clay was 342ft. Here the surface of the ground was more than 100ft. higher than at the station, and, as the beds were lying nearly flat, they would have to add some 100ft. to the thickness pierced at the station to obtain the full amount for the London Clay of that district. The sand before them was certainly Bagshot, and in all probability Lower Bagshot. If anyone present thought it Middle or Upper Bagshot he would remind that person that with the maker of that assertion lay the *onus probandi*, the natural presumption being that it was Lower Bagshot. Above this sand they saw a few feet of loam, and in the surface-workings at the top of the hill near the Crown Inn they had seen gravel, the exact age of which was doubtful, though it was certainly of later date than the beds before them.

The rain having ceased, the party then retraced its steps a few yards, and walked through Coombe Wood, reaching the road to Horndon-on-the-Hill, a few yards south of its junction with that leading to the old church. On the eastern side of the Horndon road the gravel capping the hill has been much excavated. Examination of one of the deepest of these sections—none of which are of any great size—showed, below pebbles in a very sandy matrix, sand like that seen in the pit just visited. Mr. Whitaker and Mr. H. B. Woodward were consequently inclined to think, that though there might be some ancient drift gravel (like that at Shooter's Hill and elsewhere) on the top of Laindon Hills, yet that there seemed to be no need to assume the existence there of other pebble-beds than those of Lower Bagshot age. It may be well to give here, in order to illustrate the character of the Lower Bagshot Beds of this district, the details of a section at

Brentwood, six or seven miles away, from Mr. Woodward's 'Geology of England and Wales,' p. 440.

		Ft.
Lower Bagshot Beds	Pebble-beds	15
	Brick-earth or loam and sand	25
London Clay	Brick-earth or loam and clay Sand 2 or 3 feet ... ... Brick-earth or loam and clay with septaria	50

This section affords a good illustration of Mr. Woodward's remark, on the same page as that on which this section appears that in sections near Brentwood the London Clay is seen to pass upwards into the Lower Bagshot Beds. Curiously enough, copies of the older map of the Geological Survey of the district (Sheet 1, S.E.), without Drift, show "Lower Bagshot pebble-beds," whilst the later edition, with Drift, shows "pebble-gravel" on the summit of Laindon Hill.

Few heights in the south-east of England equal Laindon as a spot from which the physiography of the surrounding district can be explained. On a clear day the spectator is enabled, by slightly shifting his position within a circle having a radius of about 200 yards from the crown of the hill, to see for a considerable distance in every direction. Eastward are the ridge on which Rayleigh and Hadleigh stand, the flats of Canvey Island, and the cliffs of Sheppey. Southward are the Kentish villages of Cliffe and Cooling, and the long dip-slope of the North Downs. Westward the most conspicuous object is Shooter's Hill, while the northward view is bounded by the high ground between Brentwood and Danbury. The broad Thames, besides forming an extremely obvious topographical guide, adds to the scene an element of beauty often wanting in extensive panoramic views, especially in this part of England. It was, doubtless, this possession of all the elements necessary to form a perfect landscape that caused Morant, the county historian, to describe Laindon as commanding the finest views in Essex, if not in England. And we have more unbiassed testimony in a work entitled, 'A Six-weeks' Tour through the Southern Counties of England and Wales' (Lond., 1768). This book, which Mr. H. B. Woodward had brought with him, and which was stated to be written by the author of the 'Farmer's

Letters,' was identified by a gentleman present as a work of the well-known Arthur Young. As might be expected, the writer treats mainly of the agricultural condition of the various counties visited, though he by no means ignores either the beauties of Nature or those of Art. His journey into the Laindon district seems to have been extremely unpleasant. He remarks that "of all the cursed roads that ever disgraced this kingdom, in the very ages of barbarism, none ever equalled that from Billericay to the King's Head at Tillbury." This road seems to have been not only extremely narrow but full of ruts of "incredible depth"; in addition, he was perpetually meeting with chalk-waggons, themselves stuck fast. Yet, he adds, "a turnpike was much solicited for by some gentlemen, to lead from Chelmsford to the Ferry at Tillbury Fort, but opposed by the Bruins of this country—whose horses are torn in pieces with bringing chalk through those vile roads. I do not imagine that the kingdom produces such an instance of detestable stupidity; and yet in this tract are found numbers of farmers who cultivate above £1,000 a year."

But his excusable indignation at the state of the roads did not prevent him from admiring the views from Laindon Hills, of which he thus writes :—"I forgot to tell you that near Horndon, on the summit of a vast hill, the most astonishing prospect that ever was beheld by human eyes breaks almost at once upon one of the dark lanes. Such a prodigious valley, everywhere painted with the finest verdure, and intersected with numberless hedges and woods, appears beneath you that it is past description; the Thames winding through it, full of ships, and bounded by the hills of Kent. Nothing can exceed this amazing prospect, unless it be that which Hannibal exhibited to his disconsolate troops when he bade them behold the glories of the Italian plains! If ever a turnpike should lead through this country, I beg you will go and view this enchanting prospect, though a journey of 40 miles is necessary for it. I never beheld anything equal to it in the West of England, that region of landscape."

This paragraph was read out to the great satisfaction of the audience.

Though our journey of 40 miles from London to Laindon and back was quick, easy, cheap, and luxurious to a degree that if foretold to Arthur Young would have seemed to him wildly Utopian, the weather prevented us from enjoying anything that could fairly be called an "enchanting prospect," and, consequently, from getting much physiographical instruction from the views. We had, in addition, to lament the unavoidable absence of Mr. Walter Crouch, through a sudden attack of illness, and the loss of the notes on the chief points of archæological and historical interest in the surrounding district which he had kindly promised to furnish. The places he had intended to mention are all easily seen from Laindon on a clear day. We may hope, however, to be more fortunate as regards both circumstances on some future occasion.

We next visited the old church on the western slope of Laindon Hills, which was kindly opened for our inspection; and the chief points of interest in it explained by the rector, the Rev. Alfred Poole. It is dedicated to St. Mary the Virgin and All Saints, and is in the Late Perpendicular style (or later), affording an example of sixteenth century brickwork. Re-ascending to the summit of the hill, tea was partaken of at the "Crown."

After tea an adjournment took place to the garden of the Inn, where, at a spot commanding extensive views to the north and east in clear weather, votes of thanks were heartily given to Mr. Whitaker for his exertions as geological guide, and to Messrs. W. Cole and W. White, of the Essex Field Club, for their services in organizing the Excursion. Mr. Whitaker then, at the request of many Members, gave some account of the geological conditions necessary to ensure success in the boring of deep wells, such as that at the Railway Station, and the party descended the northern slope to catch the London train.

REFERENCES.

Geological Survey Map (Drift Edition), Sheet No. 1, S.E.

WHITAKER, W.—'Geological Survey Memoir,' Vol. iv, pp. 327-8.

(The locality visited is marked on the map and named in the Memoir as "Langdon Hill.")

EXCURSION TO READING.

SATURDAY, JUNE 16TH, 1888.

Director : J. H. BLAKE, F.G.S., Assoc.M.Inst.C.E., of the Geological Survey.

(*Report by* THE DIRECTOR.)

The Members left London (Paddington) at 10 a.m., and arrived at Reading at 10.55, where they were met by the Director and a few gentlemen connected with various local societies. The party, numbering about thirty, proceeded southwards to Katesgrove and Waterloo Brickyards, where some of the finest sections of the Mottled Clays and Sands of the Reading Beds in the kingdom are to be seen. At Katesgrove a shaft has recently been sunk through the lower portion of the Reading Beds into the Chalk, the surface of which was found to be penetrated by tube-like cavities, similar to those at Coley and elsewhere, extending to a depth of about one foot, and supposed to be caused by boring molluscs. Specimens of the Chalk brought up from the shaft, showing these cavities filled with greensand (which latter overlies the Chalk, with a layer of green-coated flints at its junction), were carefully examined. Sections of the Reading Beds were next inspected; and then a new section showing the basement-bed of the London Clay, which is here very fossiliferous in its lower part, and contains some indurated masses here and there of marine shells and *Ditrupa plana*, the latter fossil being very abundant and characteristic of this bed. A magnificent view of the valley of the Kennet was obtained from the surface of the Drift Gravel, which overlies the basement-bed of the London Clay, and caps the high ground known by the name of Bob's Mount.

The fine sections of the Reading Beds at Waterloo Kiln were next visited, and the position of the laminated grey clays in the buff sands containing impressions of fossil leaves was pointed out by the Director.

The excursionists now made their way eastwards by Christ Church and Whiteknights' Park to Mock Beggars' Brickyard at Earley, where a new section showing the basement-bed of the London Clay (in a very fossiliferous condition) reposing on mottled crimson and grey plastic clays of the Reading Beds was well exhibited, and many fossils extracted. The party then walked to the terminus of the tramway, opposite the entrance to the Cemetery; drove westwards by two tramcars to the other terminus at the Barracks, and thence walked to Norcot Kiln and investigated a section showing High-level Plateau pebbly Gravel overlying London Clay, with its basement bed, consisting of brown loamy sand containing thin layers of grey clay, reposing on Reading Beds. These latter consist of crimson and grey mottled plastic clays, underlaid by well-stratified and false-bedded buff and whitish sands. Some black and white flint pebbles and more or less indurated casts of marine shells were pointed out by the Director as occurring here and there in a marked line at the junction of the basement-bed of the London Clay with the Reading Beds. Numerous rounded erratics, possibly derived from Triassic conglomerates, were shown to be intermixed with rounded and subangular flints and quartz pebbles in the Plateau Gravel, which extends from here southwards, covering the high ground at Tilehurst, at an elevation of from 300 ft. to 307 ft. above the level of the sea, and about 180 ft. above the Thames in this locality. No flint-implements have been found in this gravel. Having admired the fine view of the valley of the Thames and the neighbourhood of Reading from this spot, the party proceeded by the footpath to the new brickyard at Grovelands, where a fine section of the Reading Beds was exposed, consisting of mottled crimson and grey clays, underlaid by buff and whitish sands of considerable thickness.

The inspection of these beds terminated the day's field explorations, and returning by tramcars the party alighted at Cross Street, and dined together at the Queen's Hotel. After the repast the President expressed in very cordial terms his own gratitude, as well as the thanks of the Association, to the Director for the highly successful and enjoyable day they had had, to which the latter briefly responded, stating that Dr. Stevens was at the Museum ready to receive them, whither the Members immediately resorted. Having spent a considerable time at the Museum, the President, on behalf of the Association, thanked Dr. Stevens (the Hon. Curator) for his great kindness and courtesy in having the Museum specially opened for them, and for his lucid explanations of the various beautiful and valuable specimens exhibited and the painstaking care with which he had arranged them. Dr. Stevens, in a few felicitous words, expressed the satisfaction it had given him to receive them; and, after showing them the Free Library and Reading Room, most cordially took leave of them.

A brief visit was then made to the Forbury Gardens and Abbey Ruins previously to leaving for London by the 8·10 p.m. train.

REFERENCES.

Ordnance Survey Map, New Series, Sheet 128.

Geological Survey Map, Sheet 13.

Whitaker, W.—"Memoir Geol. Survey," Vol. iv, 'The Geology of the London Basin,' 1872.

EXCURSION TO GODSTONE, TILBURSTOW, AND NUTFIELD.

SATURDAY, JUNE 23RD, 1888.

Director: PROFESSOR BOULGER, F.L.S., F.G.S.

(*Report by* THE DIRECTOR.)

The Excursion was over ground in the main familiar to the Association. Traversing Caterham Valley, historical in the annals of Cretaceous geology and of the Association from the classical researches of the late Caleb Evans, the train deposited us at Caterham Terminus on the Lower Marden Park Beds or zone of *Belemnites plenus* in the Cenomanian. The neighbouring chalk-pit, now disused and much filled in with talus, was not visited, the party proceeding at once through the pass in the Downs to the Godstone Quarries in the Firestone (zone of *Pecten asper*). "Here the workings are carried along underground with the dip, about 4° to the north, the top bed of stone forming an excellent roof. About six feet of stone are worked, in beds of from six to twelve inches in thickness."* After entering the very wet galleries, with candles, for some distance, noticing the evidence of calcareous matter in the glauconitic sandstone in the short stalactites on the roof, the method of quarrying, and the hardening of the stone on exposure by the loss of its "quarry-water," the party crossed the road to the foot of the Marden Park escarpment. Here the Director called attention to the pass they had crossed, the steepness of the escarpment, crowned at this point by the Marden "Gazebo" tower, the sub-escarpment of the Firestone, and the well-wooded plain of Gault at their feet. The history of the neighbouring house in Marden Park, once the home of John Evelyn, and afterwards of Sir Robert Clayton, the "extorting Ishban" of 'Absalom and Achitophel,' and of William Wilberforce, the emancipator, but destroyed by fire a few years ago, was also touched upon; and the hop-fields on the out-crop of the Upper Greensand (*vide supra* p. 154) were pointed out. Passing the springs and swamp indicating the junction with the Gault, where a crop of *Equisetum Telmateia* recalled in miniature the forests of Carboniferous times, the next halt was called at what was described in the programme as "a fossiliferous exposure of Gault." There was a good deal of irreverent jesting anent the scanty proportions of the said "exposure," it being apparently nothing but a field-pond and the spoil-heaps produced in making it; but it serves to illustrate one of the phosphate-nodule beds near the base of the formation, yielding plenty of fragments of *Ammonites*, *Hamites*, *Inoceramus sulcatus*, *Belemnitella minima*, &c. Here the party had the pleasure of being met by their fellow-member and printer, Mr. Wolff. They then ascended the slight rise that marks the coming-in of the Folkestone Beds of the Lower Greensand and entered one of the silver-sand pits, which served as the text for a few remarks on the removal of iron-oxide by organic acids, and anon found themselves at the Clayton Arms, late White Hart, the rendezvous for dinner. The rector of the parish, Canon Samuel Hoare, Rural Dean, here met them, and kindly presided at the meal in the interesting old hostelry, much of which probably dates from the time of Richard II.[*] After dinner, noticing *en passant* the wreck of a fine old elm on the Green, where a pond indicates an argillaceous band probably belonging to the Sandgate series, a visit was paid, under the rector's guidance, to the church and to the beautiful little almshouses near by, designed by Sir Gilbert Scott, formerly a resident in the neighbourhood. By a lane with steep banks of red sand the route then lay over a rising ground to Stratton, probably a Roman station, in the alluvial valley of one of the head-waters of the River Eden, which has its source about a mile to the westward, and is said[†] to be known as Broad Mead Water. Crossing this, the ascent of the steep Tilburstow Hill—so named as being the road "till," *i.e.*, to, Burstow, a village in the Weald—was made by one of the picturesque "holloways," described by Gilbert White, and reputed to be Roman. Here the layers of "ragstone," so much more strongly developed in Kent, not many miles to the eastward, were seen dipping four degrees N., and projecting strongly from the banks. Reaching the summit of the hill, where a fine day afforded a fair view of the extensive landscape of the North Weald extending to

---

* Mem. Geol. Surv., 'The Geology of the Weald,' by W. Topley, p. 154.

---

[*] "A White Hart lodged, collared and chained, or" was the favourite badge of that monarch, which he inherited from his mother, Joan of Kent, and which appears eighty-three times upon his tomb at Westminster.

[†] 'Proc. Geol. Assoc.,' iv, 154; v, 157.

Crowborough Beacon and Eastgrinstead, with the South Downs in the extreme distance, and Leith Hill standing out to the west, the party rested. The Director seized the opportunity to give a rapid summary of the history of the landscape from the deposition of the delta deposits of the Wealden river, and of the marine Cretaceous beds above them, to their upheaval in the east and west anticlinal dome with that of the Alps, probably mainly in Miocene times, and the production, by sub-aërial denudation, of the parallel, cliff-like lines of escarpment. Then, turning westward, along the line of strike, the party walked along the top of the steep escarpment of the Hythe Beds, past the fine Tilburstow beech, 19 feet in girth, to the chert-quarries, which are worked mainly for road-metal, but present beds very similar to those of the Nutfield Fuller's-earth pits. Leaving the main road above Cold Harbour, after noting the low-lying watershed between the Eden and the Mole in the Vale of Holmesdale* to the north, a foot-path was taken to another ancient beech, some problematical earthworks, and a yew-lined track-way suggesting the Pilgrim's Way, and so to the village of Blechingley. Here turning north, through the churchyard, and descending a steep slope to Brewer Street, noticing by the way the springs thrown out by bands of Fuller's-earth and cutting gorges down the dip-slope, a detour was made to look at the gate-house of the old Manor-house. This fine half-timbered building of fifteenth century work, by the side of the Mole, was once the residence of Sir Thomas Cawarden, Chamberlain to Anne Boleyn. A beautiful lane through the red-brown ferruginous beds of the Folkestone Beds which was next traversed, suggested that the similar one between Godstone Church and Stratton was truly on the same horizon. Time did not permit a stoppage at Nutfield to visit the quarries there worked for ragstone ("Reigate Stone") and fuller's-earth; but, after ascending Pimlico Hill, a short pause was made to examine the pits, the aspect of which is so frequently changed, and to take specimens of the fuller's-earth and of the brown crystalline baryte associated with it. The long descent of Redstone Hill was then rapidly made, and the Members were glad to sit down to tea at Laker's Hotel. After the thanks of the party had been most heartily accorded to the Director, on the proposition of the President, the return train was taken for London.

---

* This is the name of the mainly Gault valley between the North Downs and the Lower Greensand, or Leith Hill, range.

REFERENCES.

Geological Survey Map, Sheet 8.

'Mem. Geol. Surv.,' Vol. iv, part 1, pp. 20-24.

TOPLEY, W., F.G.S., "The Geology of the Weald," 'Mem. Geol. Surv., pp. 120, 121, 124, 130-3, 154, 186, 234, 392-4.

MEYER, C. J. A., "On the Lower Greensand of Godalming," 'Proc. Geol. Assoc. Suppl. Vol.'

'Proc. Geol. Assoc.,' Vol. iv, pp. 153-4, and Vol. v, pp. 155-9.

EXCURSION TO RICKMANSWORTH.

SATURDAY AFTERNOON, 30TH JUNE, 1888.

(In conjunction with the Hertfordshire Natural History Society.)

Director: JOHN HOPKINSON, F.L.S., F.G.S.

(*Report by* THE DIRECTOR.)

The chief object of this Excursion was to examine sections of the Upper Chalk exposed in cuttings of the extension of the Metropolitan Railway now in progress beyond Rickmansworth, sections of the London Clay and Woolwich and Reading Beds along the same line of railway between Pinner and Rickmansworth having been examined on a former occasion.*

The route taken was through Rickmansworth and Loudwater Parks in the valley of the Chess, over the hill on the south-west into the dry valley which extends from Loudhams, between Chenies and Amersham, to the valley of the Colne at Rickmansworth, and then up the next hill to Chorley Wood Kiln.

This is not now a brickfield, but part of the garden of a private house, the occupier of which allowed the Members to inspect the section exposed. It is nearly on the edge of an outlier of the Reading Beds of about a square mile in extent, conspicuous from the valley below by forming a well-wooded eminence, and its chief interest is in showing an unusual development of the bottom bed of flint-pebbles. This bed is 12 feet in thickness, and the pebbles, some of which are very large and might almost be called boulders, are closely packed together, only the interstices left by their spherical shape being filled up with sand. It is this bed which, somewhat similarly developed, forms, in the neighbourhood of Radlett, the well-known Hertfordshire conglomerate.

---

* See 'Proc. Geol. Assoc.,' Vol. ix, p. 548.

The following is Mr. Whitaker's description of the Reading Beds seen in this section:—*

Plastic clay *(paving-clay)*.
Clayey sand, brown and light-coloured, 1½ feet.
Red-mottled plastic clay *(tile-clay)*.
Bluish-grey sandy clay *(devil)*.
Green sandy clay *(fire-clay)*, with an irregular line of ironstone nodules *(red-knob)*, below which it is more sandy, and passes into.
Green sand.
Bottom-bed—Flint-pebbles, some very large, in sand, greenish towards the top, brown and light coloured lower down; about 12 feet.

In a pit close by, the junction with the Chalk was seen; and at a little distance to the west there was evidence of the junction of the Reading Beds with the Chalk in a swallow-hole formed by water falling as rain on the Reading Beds and flowing over or percolating through them to the edge of the Chalk, on meeting which it sinks through and dissolves it. This swallow-hole now holds water, having evidently been artificially plugged by puddling in order to form a pond.

A footpath was then taken down to Chorley Wood Bottom, by which the Common was reached, and the return walk to Rickmansworth was commenced where a cutting is being made through the south-western corner of the Common.

The route was now entirely along the new railway-line. An immense "pipe" in the Chalk first attracted attention, and the Director showed the relation such pipes bear to swallow-holes, the chalk originally in them having been gradually dissolved and carried away by water holding carbonic acid in solution, and its place having been taken by the insoluble portions of the superincumbent strata, in this case chiefly sand and flint-pebbles. The probable origin of the dry valley before mentioned, part of which was now to be traversed, was then touched upon, and it was shown that it could be accounted for if the water-level in the Chalk had been in former times a little higher than it is now, when water would have flowed on the surface of the ground, instead of, as at present, only through the pervious chalk underground. This dry valley has been taken advantage of in the construction of the new line, which would without it have been a continuous cutting from Rickmansworth to Chorley Wood Common.

---

* 'Geol. Lond. Basin,' p. 217.

In the course of the return walk two deep cuttings were passed through, showing sections, about 90 feet in height, of the Upper Chalk entirely free from "pipes," owing to clay being on the surface and forming an impermeable capping, instead of gravel or sand, which allow water to percolate through them.

On arrival at Rickmansworth the Members of the two Societies had tea and then dispersed to their several destinations. The party numbered forty.

REFERENCES.

Geological Survey Map, Sheet 7.

HOPKINSON, J.—Introduction to Pryor's 'Flora of Hertfordshire,' 1887, pp. 13-21

WHITAKER, W.—'Mem. Geol. Surv., on Sheet 7,' 1864, pp. 38, 39.

——— 'Geol. London Basin,' Part i, 1872, p. 217.

——— 'Guide to the Geology of London,' 3rd Ed., 1880, pp. 23-28, and 35-38.

EXCURSION TO LOAMPIT HILL, LEWISHAM, AND WEST COMBE PARK, GREENWICH.

JULY 7TH, 1888.

Director: T. V. HOLMES, F.G.S.

(*Report by* THE DIRECTOR.)

On emerging from Lewisham Junction Railway station the party bore to the right and proceeded along Loampit Vale. After passing beneath the main line railway bridge it turned to the left and then again to the right, up Brookbank Road. During the last ten years there has been much building between the Loampit-Hill sections and the main line of the South-Eastern Railway lower down the hill, and Brookbank Road is one of the new streets. At the top of this road there appeared a fine clear section, about 20ft. in height, showing the uppermost beds of the Woolwich series surmounted by the thin pebble band at the base of the London Clay, and seven or eight feet of the clay itself. South and south-west of this point the London Clay grew thicker and thicker, while north and north-east were the outcrops of the lower Woolwich Beds, the Thanet Sand, and the Chalk. The feature of special interest in the section facing the Brookbank Road was the presence of a very clearly shown reversed fault. Its throw was only about 2ft., but the existence of a reversed fault at all in beds like these is a noteworthy fact, though they are not uncommon in mountain-chains and much disturbed districts. It need hardly be said that the peculiarity of a reversed fault is that it hades or inclines to the upthrow. Consequently a boring made close to its line might pierce through the same beds twice. In this case the line of the fault, instead of being, like an average fault, some 15 or 20 degrees from the vertical, was found to be only 15 or 16 degrees from the horizontal.

Mounting to the top of the section just described, and gazing in a westerly direction, the excavations made for some now disused brickworks showed the London Clay dipping into the hillside, the pebble band at its base, and the light-coloured sand with clay partings, and clay with sandy partings, being visible here and there below. In the side of an excavation at some little distance, and a little below the general level of the pit, a dark band indicated the presence of a bed of lignite, which was not inspected more closely in consequence of the wetness of the ground.

The party then retraced its steps a little in order to see the beds of the Woolwich series which underlie those already noticed. The pit displaying them lies on the northern side of the Brookbank Road, and is now enclosed and used as a storeyard. Being, however, nearly semicircular in shape, the various strata were fairly well seen from the top, though a few of the more adventurous climbed down the sides of the pit in order to obtain specimens. Here were visible the shell-beds of the Woolwich series, the middle, or oyster bed, standing out prominently, while the softer *Cyrena* beds, above and below, had been worn back. Below the shell-beds thick pebble-beds were seen.

Proceeding northwards, over ground from which the Woolwich Beds had been largely removed, the large pit of Chalk capped by Thanet Sand was next visited, the evenness of the junction, from the absence of pipes, causing some surprise. Thence emerging into the Lewisham high road, the party returned in the direction of Lewisham Junction Station, and ascending Lewisham Hill crossed Blackheath and the south-east corner of Greenwich Park, and entered Westcombe Park. (See paper on these sections, 'Proc. Geol. Assoc.,' Vol. viii, p. 59.) Near the junction of Foyle Road with Humber Road the shell-beds of the Woolwich series were visible on the southern side of the latter road, the oyster bed, however, being absent. The pebble-beds of the Blackheath series were here seen to rest directly on the shell-beds, though this was not so clearly manifest as in 1883 (when the Association last visited this spot) owing to the carting away of much of the pebble-beds at this point since that time. Proceeding eastward, the presence of the shell-beds, which throw out the water percolating through the permeable gravel and sand above, was marked by the wetness of the ground on the south side of Humber Road. Near the junction of Humber and Coleraine Roads, the bridge over the railway near, but west of, Westcombe Park Station, enabled the party to see the Thanet Sand, which forms the whole of the railway-cutting westward on its southern side, the much lower bank on the north being partly composed of overlying orange-coloured valley-gravel. Thence, ascending Beaconsfield Road, a wet place with fragments of broken shells was crossed, and the whitish sand, with thin clayey laminations, which there appears to directly overlie the shell-beds, was inspected. This sand has been largely carted away since 1883. The modifications in this section that have consequently taken place since that date make it probable that this whitish sand, which, as we have seen, disappears at the junction of Foyle and Humber Roads, should be classed with the Blackheath rather than with the Woolwich Beds.

The party here dispersed, some to get a train at Westcombe Park Station, close by, while others walked westward through Greenwich Park.

REFERENCES.

The details of the Loampit Hill section are given in Whitaker's 'Geology of the London Basin,' p. 127, and in the same author's 'Guide to the Geology of London and Neighbourhood.' Also 'Proc. Geol. Assoc.,' Vol. iv, p. 114. The Westcombe Park sections are described by T. V. Holmes, 'Proc Geol. Assoc.,' Vol. viii, pp. 59-64.

EXCURSION TO BEDFORD AND CLAPHAM.

SATURDAY, JULY 21st, 1888.

(In conjunction with the Bedfordshire Archæological and Natural History Society.)

Director: A. C. G. Cameron, H.M. Geological Survey.

(*Report compiled from local papers.*[*])

Leaving St. Pancras at 10.10 a.m. the party reached Bedford at 11.16, and were cordially welcomed by the Bedford contingent. From the railway they walked to the Pumping Station on the Clapham road, where they were met by the Borough Surveyor (Mr. J. Lund), Mr. Joseph Miller, and Mr. Charles Franklin, and the Deputy-Mayor (Mr. Jabez Carter) put in an appearance at a later stage. Under the direction of Mr. Lund a full inspection was made of the cut or heading in the limestone from which the town water-supply is derived, and which runs under the roadway leading down to the Pumping Works. By the side of this road are two wells fifty feet deep, at the bottom of which the water can be seen running in a strong stream. The water also trickles from the limestone, which is thirty feet thick, and from the rock to the surface the wells are bricked round. Connected with the heading is a large well or boring, the upper part of which has been enlarged and forms a chamber in the rock. This chamber is below the garden at the Pumping Station, and close to the river. It is about thirty feet long, nearly the same depth, and twenty feet wide; and the average depth of water kept in it is from two to three feet. Mr. Lund explained that as the town developed it was found necessary to extend the heading, which doubled the supply of water, and the daily consumption was now from three to four hundred thousand gallons. Several of the party entered the chamber, and others inspected the engine-house.

The company thence proceeded to the neighbouring brickyards and stone-pits, by the kind permission of Mr. Charles Franklin. Mr. Cameron pointed out the geological features in the various pits, commencing with the stone-pits nearest the river, and working upwards to the Clapham Road, and in ascending order. The first pit visited showed the Ostrea beds of the Great Oolite limestone, and clay, beneath which there is apparently a great thickness of Liassic clay. Above the Oolite limestones lay a fine exposure of the purple and black clays of the Cornbrash, locally known as "Pendle rock." There was here an abundance of calcite and oyster shells. The Lower Oxford, consisting of dark clay, with much selenite and race, was next observed. In the upper pits, where brick earth is obtained, there was a fine section of Kellaway's Rock, consisting of a blue loam, which passes upwards into yellow irony sand, enclosing hard masses of calcareous sandstone known as doggers. Mr. Franklin had caused some of these to be bared, so that they could be easily inspected. The uppermost strata examined were those of the Upper Oxford, partly covered by Boulder Clay, which at this point comes down the hill almost to the river's edge. In the brickyards the process of making bricks was observed with great interest, and Mr. Cameron made the following remarks on the brickmaking industry :—

---

[*] 'The Bedfordshire Times and Independent' and 'The Bedfordshire Standard.'

"Digging clay for brickmaking purposes results in a hole, which may be either a shallow excavation of three or four feet, or a pit ten or twelve feet deep. Sometimes, as is the case at Cleat Hill, the clay is worked from the edge of the flat, up the hill slope, until it meets the cap of Boulder Clay above. In this way the whole face of the hill may be laid bare. It would be impossible in a paper such as this, to enter upon the whole art of brickmaking, nor would it add much to our practical knowledge of the subject. The interest to this Association, lies more in the manufacture of brick out of Bedford clay, and on this I am able to offer a few remarks. All Bedford bricks are hand-made or hand-machine-made, there being but one brickwork (as far as I know) in the neighbourhood, where steam-power is employed. The brickearth is the Oxford Clay, prepared alone, or with an admixture of the "mild clay" of the builders, the Kellaway loam and sand, which is usually obtainable in the same brickfield. Boulder Clay is not used. In this particular field in which we are assembled, the Lower Oxford beneath the Kellaways, is the clay dug; this being mixed in the pugmill with the blue Kellaway loam, produces an efficient brickearth. The brickmaking season commences in April, and is carried on with great activity throughout the summer. In October it is practically over, as it seldom happens that any bricks are made at a later time of year, or during the winter months. Still, winter is a busy time, for it is then that the clay is dug, and stacked, and piled in heaps, and left to weather in the frost, which breaks up and crumbles the lumps. In spring, the heaps are turned over and sufficient water added to give plasticity to the mass; care being taken in stirring the clay to pick out the fossils, or stones, as these, if allowed to remain, crack the clay in drying, and burn into white lumps, making the bricks unsound, for as these lumps weather out, they leave the bricks riddled with unsightly holes—and if a piece of limestone no bigger than a pea be allowed to remain, it will destroy any brick into which it finds its way. Hundreds of *Gryphœa* lie amongst the clay in some brickyards, and where there are so many not a few escape observation, so that unwittingly, the shell of the departed lamellibranch becomes cremated at the last. Scarcely a shell of any kind can be found at other brick-pits—such an unfossiliferous bed being, of course, all the better for brickmaking purposes. Again, there are pits where *Belemnites* can be gathered by the bushel. In April, the clay is ripe or mellow, and in readiness for the moulder. A brick-mould, is a kind of wooden box without top or bottom, into which the clay is dashed so as to fill it. There is a good deal of water or "slop" used in the operations, both the wooden striker to remove the superfluous clay, and the mould, being constantly kept wet. This necessitates well-sinking as a not unusual addition to the general arrangement of a brickwork—*i.e.*, if no natural water advantages are available. Sand, such as that from Flitwick, is used to dust the moulds and keep them from sticking. All these operations are executed with great dexterity, and it is astonishing how great a number of bricks are made in a day. With a well-appointed yard, a man can make from 1,000 to 1,200 a day, of twelve or fourteen hours, and he generally works that length of time. With helpers to wheel away and stack, 5,000 are made. When steam power is used, 50,000 is the output for the day. Here, with ten moulders, 10,000 to 12,000 bricks are made in a day. It is on record, and as not a solitary instance, that " in Cumberland, one Josiah Rush, performed the feat of making 1,000 bricks in an hour, 100 in five minutes, and twenty-six in one minute," which is, I believe, about a barrowful.* A raw brick has to be dried with great care, as much depends upon the condition they are in, when placed in the kiln. They must be kept from sun, wind, rain, and frost; exposure being as detrimental now, as beneficial in the earlier stages of preparing the clay. Draughts are very injurious, as they cause the bricks to dry faster on one side than on the other; boards, therefore, are generally to be seen placed round the drying-sheds, to keep these out, and maintain an equable movement of the air. Kilns for burning, are erected in many ways, and scarcely any two are exactly alike. In Bedfordshire, the kiln most often seen is a rectangular one, known as the furnace kiln, having the furnaces running underneath the whole length of the structure. The bricks are placed crossways inside, so as to leave spaces from top to bottom for the heat to circulate throughout. At first there is a good deal of steaming; and when this ceases the bricks are dried. The fires are then increased until the burning is complete. Before removing the bricks, the fires are allowed to go out, and the kilns to gradually cool down. The time allowed in the kiln varies with the weather, the previous drying, the size of the kiln, and to some extent with the demand for bricks; but if put in on a Monday they are usually taken out the following week. The main mass of Oxford Clay, being buried here almost to the water's edge, beneath the Boulder Clay, it is not conveniently available for brickmaking purposes. What is used, being, as I have already said, the Lower Oxford, a clay bed subordinate to the Kellaways. The Cornbrash Clay—the purple clay beneath the limestone—is not used, or only to the small extent of having the upper two feet sometimes mixed in the pugmill with the other beds of clay and loam.

---

* 'Carlisle Journal.'

"*Brick Colouring* is an interesting feature in the art of brickmaking—besides being an important item in its commercial value. The colour of a brick depends not altogether upon the natural colour of the clay, but upon the amount of iron present in the clay, modified in some cases by the firing in the kiln. For the same reason, I suppose, that a lobster is spoken of as being red, when he is really bluish black or black, brickmakers often speak of their clay as red or white, when they really mean that the bricks are these colours, without reference to the colour of the earth employed—which, as likely as not, may be blue or grey. I do not, however, maintain that a raw lobster turns red if boiled, for the same reason that crude clay is red when baked, which is, of course, due to its containing oxides of iron in its composition. The colouring of clay depends mainly upon the presence of iron, in various proportions and states of combinations. I say mainly, because in some Oolitic and other clays the colouring power of the iron is obscured by carbonaceous matter. The prevailing colours that iron gives to clay are grey and red, according as the iron is present in the form of a protoxide, or hydrated peroxide. Oxford Clay, Gault, and London Clay come under the head of grey clays. Either of these coloured clays will make a red brick. There are only grey clays in Bedfordshire, which weather yellow in their upper part, and from these are produced the red building bricks, mixed bricks, and the pale buff or cream, generally called white bricks. No essential difference exists in the colouring matter or aspect of a clay that burns yellow or pale buff, and those that burn red, the depth of colour depending mainly on the amount of iron present, the buff shades regularly graduating into the deeper shades of red. There is an analysis by the late Dr. Voelcker of Oxford Clay, Brickworks, Chippenham, Wilts, which is as follows :—

" Protoxide of iron		1·12	per cent.
Sesqui oxide	„	3·25	„
Bisulphide	„	1·10	„
Sulphate lime	„	1·37	„

and crystals of selenite distributed through the strata." It is only a partial analysis, but as far as it goes, it is a typical analysis of Oxford Clay generally. The remainders are principally alumina and silica, say ninety parts, with perhaps carbonaceous matter in small quantities. Here then is about 5½ per cent. of iron, and this quantity of iron in the Bedford Clay sufficiently accounts for the bricks and kindred fabric, ranging in colour from cream or pale buff, to bright and dark red. Had there been more of iron, say eight to ten per cent., the bricks would have been of a blue or almost a black colour."

On their arrival in the Clapham Road, the party found several conveyances awaiting them, and they were thence driven to Clapham Church, were the Saxon tower was inspected with great interest. The party having seated themselves in the church, Canon Haddock, from the chancel steps, delivered a most interesting address on various points of interest in the church. He stated what was known about the ancient tower, described the more recent additions to the edifice, interspersing his remarks with some criticism, and alluded at some length to a beautiful marble monument, the work of Grinling Gibbons. The tower, which is eighty-one feet high, is built of native limestone, and is noteworthy for its extreme simplicity and rudeness of construction, and is one of the best and most remarkable of the remaining examples of early Saxon work in the kingdom. The foundations extend only about a foot into the ground; the walls at the base are 3ft. 10ins. thick, the outside is roughly plastered, and the inside remains jagged as constructed.

The party then droveto the New Park at Bedford, passing through Clapham Park, by kind permission of Mr. James Howard. In due time they arrived at the New Park, where they were invited into the Pavilion, where a most hospitable repast had been provided by the Mayor, Mr. Hawkins. After creature comforts had received due attention, the Mayor proposed the health of the Association, expressing his regret that the state of his health had prevented his accompanying them, since as Mayor of that essentially educational town he was naturally much interested in science, especially in so progressive a science as geology, and was very pleased in the name of the town to offer the Geologists' Association a very hearty welcome. The President replied, thanking the Mayor for his very gracious reception, and for his address, marked as it had been by so much common sense and scientific research, and also thanking Mr. Lund, Canon Haddock, Mr. Franklin, and the other gentlemen who had assisted them during a very interesting day. Alderman Carter then proposed the health of Mr. Cameron, Dr. Coombs that of Alderman Hurst as representing the Beds. Natural History and Archæological Society, and Alderman Hurst that of the ladies, to which Miss Forster replied.

The company then proceeded to the Park Gates, which were described by Mr. Joseph Miller, and thence down the De Parys Avenue to the Bunyan Monument, which was duly inspected. A few botanists then walked to the Embankment and Newnham Bridge, others took a boat on the river, while the main body visited the Modern School Museum, where the curator, Mr. Taylor, was in attendance to receive them, and great interest was taken in the geological collections. Next they visited the Museum Room of the Beds. Archæological and Natural History Society, examined the specimens and books belonging to both branches of that Society, and were shown a typical series of fossils from the Chalk by Mr. J. Saunders. The Embankment and New Foot Bridge were also visited, and one or two engineers in the company examined, with interest, the last-named structure. In this agreeable manner the time was spent until the party departed by the return train to London.

REFERENCE.

Geological Survey Map, Sheet 52, S.E. and S.W.

ON THE LOWER DIVISIONS OF THE CARBONIFEROUS ROCKS OF THE FOREST OF DEAN.

BY E. WETHERED, F.G.S., F.C.S., F.R.M.S.

(*Read July* 6, 1888.)

In Gloucestershire we have two coal-fields, that of Bristol and that of the Forest of Dean. These two, together with that of Somersetshire, are regarded as outliers of the great South Wales coal-field. Sir Andrew Ramsay states * that the separation was brought about by long-continued denudation, which has swept away thousands of feet of strata bent into anticlinal and synclinal curves. He further remarks † that "the intervening spaces are anticlinal and the basins synclinal curves, and therefore it is not only possible, but probable, that other coal-basins may lie far to the east beneath the Oolitic, Cretaceous, and Eocene strata of the London basin." These conclusions have generally been accepted, and I am not going to dispute their correctness. I shall, however, show that in the Forest of Dean there are geological features which differ greatly from those of contemporaneous rocks in the Bristol area. As this is important, and to a great extent new, I shall in this paper have something to say as to the correlation of the Carboniferous rocks of the Forest of Dean with those of Bristol. But as this paper is to have special reference to the visit of the Association to the Forest of Dean, I shall confine myself to strata below the Coal Measures, as it will be impossible on that occasion to see more.

As typical of the Lower Carboniferous rocks of the Bristol area, I take the exposure in the gorge of the River Avon at Clifton, which, as Sir Henry De la Beche pointed out,‡ does not materially differ in thickness from the same formation in the Mendip Hills of Somersetshire and in South Pembrokeshire. Sir Henry gave * the thickness as follows :—

---

* 'Physical Geology and Geography,' fifth edition, p. 35 (1878).
† *Loc. cit.*, p. 122.
‡ 'Mem. Geol. Survey,' Vol. i, p. 112.

	Feet.
Upper mixture of Sandstone, Marls, and Limestones ...	400
Central portion of series	1438
Lower shales	500
	2338

In a recent paper of mine † I have made some alteration in the above classification, thus :—

	Feet.
Stage C, ‡ Upper Limestones...	100
Stage B, Middle Limestones	1620
Stage A, Lower Limestones, including (i.) Black Rock, 490 feet, (ii.) Lower Limestone shales, 500 feet	990
	2710

The Carboniferous Limestone series in the Forest of Dean have not received anything like the amount of attention which has been bestowed upon the same rocks in the Bristol coal-field. Sir Henry De la Beche gives a section § which he compares with that of the Avon, and points out that there is a great diminution in the thickness of the beds in the Forest of Dean, which he estimates as follows :—

	Feet.
Upper mixtures of Sandstones and Marls	146
Central portion...	480
Lower shales	165
	791

Thus, Sir Henry remarks, ‖ "the central portion of the Carboniferous series, 1,438 feet in depth at Bristol, become 480 feet in the Forest of Dean. The lower beds are diminished about one-third, the central portion the same, and the upper beds very nearly in the same proportion."

---

* *Loc. cit.*, p. 129.

† 'Quart. Journ. Geol. Soc.,' Vol. xliv, p. 187 (1888).

‡ The introduction of the term stage and the letters refer to Professor Hull's classification, 'Quart. Journ. Geol. Soc.,' Vol. xxxiii, p. 631 (1877).

§ 'Mem. Geol. Survey,' Vol. i, p. 129.

‖ *Loc. cit.*, p. 129.

In a paper which I communicated to the 'Geological Magazine'* I classified the rocks thus:—

	Feet.
Stage C, Upper Limestones, including the Whitehead and Crease Limestones	116
Stage B, Middle Limestones	360
Stage A, Lower Limestones	130
	606

Since that paper was written I have examined exposures of the upper Limestones not previously available, especially one at the Wilderness Cement Works near Mitcheldean, which has enabled me to make a more detailed examination. These details will be referred to later on, and I will only mention here that the thickness of 116 feet may be a fair average for the whole coal-field, but it is too great for the northern end, where the upper series are not so well developed as at the southern end. The following statement will be more correct for the former district, though the beds vary considerably even over a small area:—

Upper Limestones.	Feet.
Whitehead Limestone	30
Crease Limestone...	35
	65

Above the Whitehead series sandy beds appear in some places associated with argillaceous flagstones and some small plant remains. These constitute a thickness of about 15 or 20 feet and are succeeded by the true Millstone grit. Sir H. De la Beche puts the thickness of the Millstone grit in the Bristol area at 950 feet, and that of the Forest of Dean at 270 feet, which I accept.

The Lower Limestone Shales.

An examination of the Geological Survey Map shows that the Old Red Conglomerate appears as a belt around the edges of the Carboniferous Limestone. This conglomerate is followed by a remarkable series of many-coloured sandy beds and green micaceous shales, which lie between it and the Carboniferous Lower Limestone shales. These are the so-called "Passage beds." In the 'Proceedings of the Cotteswold Naturalists' Field Club' for 1867 there is a detailed section of them, as they were exposed in the "deep cutting" near Drybrook, made by Mr. W. C. Lucy and Mr. John Jones. Since then the beds have been cut through in the course of the new railway from Coleford to Monmouth, and for a very carefully-made section (fig. 1) I am indebted to Mr. A. Stannard, C.E., the engineer who made the railway.

---

* n.s., Dec. iii, Vol. iii (1886), p. 529.

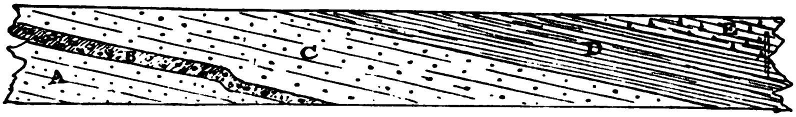


FIG. 1. Section at Redbrook, Gloucestershire, exposed in cutting on the Coleford Railway, showing beds between the Old Red Conglomerate and the Lower Limestone Shales.

A. Old Red Sandstone. B. Old Red Conglomerate. C. Sandstone. D. Sandy Calciferous Beds and Shales. E. Lower Limestone Shales.

Horizontal scale four times the vertical scale.

The Old Red Conglomerate is here shown as only 12 feet thick, and is followed by red sandy beds, which may, perhaps, be termed Upper Old Red Sandstone. Mr. Stannard put these at 82 feet. Then follows 70 feet of loose Calcareous Sandstone, in some beds of which are nodular fragments of Limestone. Messrs. Jones and Lucy give the total thickness of the beds exposed in the deep cutting near Drybrook at 247 feet. A reference to the Geological Map will show that the two exposures of the beds referred to are sufficiently far apart to dispose of the idea that they are characteristic of any one locality, and to justify the belief that they underlie the limestone shales throughout the area of the coal-field. Among the minerals which I have detected in these beds are, mica, very abundant in green shales, felspar, tourmaline, zircon, rutile (?), and quartz. The remarkable variation in colour which the strata present is due to oxides of iron and manganese.

The Lower Limestones consist of one division only, which corresponds with the Lower Limestone shales of the West of England. The "Black Rock," or upper portion of the Lower Limestones of the British coal-field, is not represented in the Forest of Dean. The Black Rock is a limestone made up chiefly of the remains of Encrinites, and constitutes the local Encrinite Limestone at Bristol. In the Lower Limestone shales of the Forest of Dean there is one very interesting Encrinite bed, which is typical of the northern end of the coal-field, but it is only one foot thick, and cannot be correlated with the Black Rock. Some of the Encrinite joints in the Forest of Dean bed are interesting from the fact that the central portion is pentagonal, which centre is surrounded by a circular outer margin. Specimens of these are figured in my paper in the 'Geological Magazine,'* but the photographic process by which the objects were reproduced was not suitable, and the figures are consequently unsatisfactory.

The other limestones which constitute the Lower Limestones of the Forest of Dean are some of them largely made up of Ostracoda ; some beds are little else than the valves of those small Crustacea. Polyzoa are numerous in the Encrinite bed, and occur in others. *Rhynchonella pleurodon* is very numerous in some of the black shales between the beds of limestone, and on the shales weathering may be collected in great numbers. In these shales I have detected the spores of plants, details as to which will be found in the 'Proceedings of the Cotteswold Naturalists' Field Club' for 1883-4. They are interesting as being allied to spores which Mr. E. T. Newton† discovered in Tasmanite and "Australian White Coal," and also to similar vegetable remains which occur in great abundance in the Huron shales of Ohio. The exact horizon of these American shales is a debateable question, but they belong either to the Upper Devonian or Lower Carboniferous. Consequently the Black shales of Ohio occupy much the same position as those in the Forest of Dean, and it is, therefore, interesting to discover these vegetable remains which are closely allied, in strata of about the same geological horizon, though in localities so far apart. Sir William Dawson regards‡ the spores as Rhizocarps, and as belonging to his genus *Sporangites.*

There is also an organism of some interest which was first discovered in the Lower Limestone shales of the Forest of Dean, and the Association will have an opportunity of obtaining limestone largely made up of it. I refer to my genus *Mitcheldeania.* It was first described in the 'Geological Magazine,'§ but for the same reason that the other illustrations in the plate are not satisfactory, so with the figure of *Mitcheldeania* it is difficult to form a correct opinion as to the true nature of the organism. I have since described it in the 'Proceedings of the Cotteswold Naturalists'

---

* n.s., Dec. iii, Vol. iii (1886), Pl. xiv, Figs. 1 and 2.

† 'Geol. Mag.,' n.s., Dec. ii, Vol. ii (1875), p. 337.

‡ 'Geological History of Plants,' p. 52, 1888.

§ n.s., Dec. iii, Vol. iii (1886), Pl. xiv, Fig. 6, p. 535. The name is taken from the locality, Mitcheldean.

Field Club,'* and Professor Alleyne Nicholson has referred to it in the 'Geological Magazine.'† Briefly stated, the genus *Mitcheldeania* is an organism consisting of systems of tubuli, the whole occurring in oval masses, or encrusting the remains of other organisms. The larger tubuli appear to be zoöids, and the smaller probably contained the living matter. There is also interstitial tissue, which is traversed by still more minute branching tubuli. The first species of the genus I named *M. Nicholsoni*, after Professor Nicholson, and provisionally referred it to the *Hydractiniidæ*, as allied to the *Stromatoporoids*. Professor Nicholson has since described‡ and figured a larger species, *M. gregaria*, from the South of Scotland, and in the course of his remarks says: "In spite of the extreme minuteness of its tissues, the genus *Mitcheldeania* may, I think, be referred with tolerable certainty to the *Cœlenterata*. Admitting its Cœlenterate affinities, it would seem almost certain that the genus must be placed in the series of the *Hydrozoa*. There is, however, no known group of this class within which *Mitcheldeania* can be satisfactorily located. Its closest affinities seem to be with the Hydrocorallines, and in this connection I would particularly draw attention to the resemblance of the interstitial tissue of *Mitcheldeania* to the cœnenchymal tissue of certain species of *Allopora*. On the other hand, all the known Hydrocorallines possess zoöidal tubes which are enormously larger than those of *Mitcheldeania*; and there are other morphological features in the latter genus which would preclude its being actually placed, with our present knowledge, in the group of the *Hydrocorallinæ*.

The following is a list of the fossils which have been found in the Lower Limestone shales of the Forest of Dean:—

HYDROZOA—
  Mitcheldeania nicholsoni (Weth.).
CRINOIDEA—
  Poteriocrinites crassus (Miller).
  Rhodocrinites (?) (Miller).
OSTRACODA—
  Kirkbya variabilis, J. & K.
  „ *plicata*, J. & K.
  Cytherella extuberata, J. &. K.
  Bythocypris sublunata, J. & K.

---

* 1885-6, p. 79.

† n.s., Dec. iii, Vol. v (1888), p. 19.

‡ *Loc. cit.*, p. 17.

Darwinula berniciana (?), Jones.
Leperditia okeni, Munster.

POLYZOA—
Fenestella tuberculo-carinata (Ether., junr.).
Ceriopora similis (Phill.).
Rhabdomeson gracile (Phill.).

BRACHIOPODA—
Athyris royssii (L'Eveillé).
Rhynchonella pleurodon (Phill.).

GASTEROPODA—
A fossil allied to *Murchisonia angulata*.

The only reference which I need make to the above list relates to the Ostracoda. My specimens were sent to Professor Rupert Jones and Mr. J. W. Kirkby, who in a note appended to a paper of theirs* refer to the discovery of the following Ostracoda from a boring at Gayton, in Northamptonshire :—*Kirkbya variabilis, K. plicata, Cytherella extuberata, C. attenuata, Bythocypris sublunata,* and *Macrocypris Jonesiana.* The authors then refer to the list which I give of forms found in the Forest of Dean, and make the following remarks :—"Quite recently Mr. E. Wethered, F.G.S., of Cheltenham, has favoured us with specimens from the Lower Limestone shale of the Forest of Dean. Curiously enough, these specimens are almost exactly similar in species and individual abundance to those of the Gayton Boring."

The Middle Limestone.

I have not myself as yet been fortunate enough to obtain a fossil from these beds, and the explanation appears to be that they are extensively dolomitized. I cannot speak so confidently of the limestone at the southern outcrop, but all the exposures that I have seen are those of dolomitized limestone. An analysis made by Mr. Ernest Wiltshire, F.G.S., and myself gave the following results :—

Moisture	·02
Organic matter	6·17
Carbonic acid	44·01
Insoluble residue	1·06
Soluble silica	·10
Ferrous oxide	·63
Lime	30·24
Magnesia	17·50
Soda	·25
	99·98

---

* 'Quart. Journ. Geol. Soc.,' Vol. xlii, p. 504 (1886).

Iron ore occurs in the Middle Limestone, and this is especially so at the northern end of the Coal-field, where it was worked by the Romans, as well as in recent times. Referring to the occurrence of this hæmatite, Sir H. De la Beche says:—" The Dean Forest section presents us with an interesting local accumulation of peroxide of iron intermingled with the calcareous deposits of the time; so that we should regard the iron as having constituted as much a portion of the rocks in a particular part of the general series as any other marked beds. . . . Although, in endeavouring to account for the position of the iron ore in the Carboniferous Limestone of Dean Forest, we may, from existing knowledge, be led to suppose that it was formed in the sea, amid the marine accumulations with which it is associated, so that it may not have been a bog iron ore of that geological period, still its dispersion at the same time over so wide an area would induce us to infer that the peroxide was thrown down from water in which the iron had previously been, in some soluble form, spread over the space required."* The result of my examination of these ores makes it difficult to accept the explanation advanced by Sir H. De la Beche. It is true that in some cases the ore has a stratified appearance, but I am still disposed to regard the deposit as an after in-filling, or rather, precipitation. In the 'Geological Magazine' for 1882 (pp. 522-525) there is a paper of mine 'On the Origin of the Hematite Deposits in the Carboniferous Limestone,' from which I venture to quote:— "To sum up my conclusions on the subject of this paper, I regard the so-called pockets of hematite in the interior of the Limestone as caverns, into which water has percolated charged with the carbonates of lime and iron. On the excess of carbonic acid being given off, and a complete saturation taking place, carbonate of lime first separated in the crystalline state; and subsequently, when oxidation was possible, peroxide of iron was thrown down. As to the source from which the iron was derived, I think it possible that some portion may have come from the Coal Measures and Millstone grit prior to denudation by the Triassic Sea, but that the greater portion was derived from the Trias rocks by the percolation of water containing carbonic acid." In support of the conclusions just stated, I make another short quotation from the same paper (p. 523):—" A practical instance of what I have just described (referring to the deposition of iron oxide) was seen when down the Easton Colliery, near Bristol, a few months since. Water was issuing from old workings, and on flowing into a road of the mine where fresh air was travelling, a ferruginous deposit took place. Again, I once had occasion to descend an old shaft of a coal-mine which had not been worked for many years; near the bottom of the shaft water was issuing from the old workings, and there was a deposit of peroxide of iron about half-an-inch deep. On penetrating further into the workings where the atmosphere had been, until recently, strongly diluted with carbonic acid, there was an entire absence of such a deposit." Should the Association visit the Carth iron-mine, near Cardiff, I think the Members will come to the conclusion that the so-called pockets are really caverns, or underground water-courses, in which iron has been deposited in the way I have indicated.

---

* 'Mem. Geol. Survey,' Vol. i, p. 130.

Comparing the middle division of the Carboniferous Limestone series of the Forest of Dean with the contemporaneous rocks in the Bristol and Somersetshire coal-fields, we again find a marked difference. In the latter areas, the Limestone is largely made up of foraminifera and *Calcisphæræ*, and to a less extent of fragments of shells, polyzoa, joints of crinoids, and corals. Dolomite occurs at three horizons, but is unimportant.

Upper Limestones.

I have before stated that the Upper Series consists of two distinct Limestones, namely, the Crease and the Whitehead. At what may be regarded the top of the Middle Limestone I have observed an Encrinital bed, and it is at this horizon that I draw the line between the Middle and Upper Series. This Encrinital Limestone varies considerably in thickness: in some places it is less than one foot; whilst in others it is as much as four feet or more. This variation in thickness is a feature of the Upper Limestones; and indeed, it would be difficult to find two localities where identical measurements could be obtained.

The Crease Limestone.

It is in this Limestone that the chief deposit of hæmatite ores occurs. The origin of this mineral in the Middle Limestone has been dealt with, and what I have said in reference to it applies also to that which occurs in the "Crease."

The structure of the rock in close proximity to the ore is peculiar, and difficult to understand. Seen in thin sections it appears to be made up of angular calcareous fragments, and in my paper in the 'Geological Magazine' * I have called it a calcareous grit. I am not, however, sure that I was right in so terming it, for more extensive observations lead me to believe that it is a limestone which has become crystalline.

Other portions of the "Crease," recently exposed at the Wilderness Cement Works near Mitcheldean, are very fossiliferous, the fossils being chiefly *Producti*, but much crushed. Thin sections show remains of these shells, especially the spires, some joints of Encrinites, a few *Calcisphæra* and granular calcareous fragments which could not be determined. The upper beds of the Crease exhibit a fine Oolitic structure. The nucleus of the granules is sometimes a portion of an Encrinite joint, but as a rule the nuclei are not well preserved.

The Whitehead Limestone.

The beds which constitute the uppermost of the whole Carboniferous Limestone series in the Forest of Dean are locally known as the "Whitehead" Limestone. The name appears to have been suggested from the peculiar whiteness of some of the beds, and from the fact that no hæmatite occurs in them, and consequently, in local mining dialect, it is termed the "head."

The true limestones are separated by shales and argillaceous limestones, and about the middle of the series there is a peculiar deposit of concretionary or nodular limestone and blue calcareous clay, the whole averaging about 7 feet thick. The series terminates in a thickness of about 12 feet of white limestone, tinged with gray, locally known as the "Whitehead Block."

The following are my notes on thin sections made from specimens of the above Limestones.

1.—The bed which rests upon the "Crease," and is locally termed the "Lid." It is made up of small variously-shaped fragments of granular Limestone. The only organisms which could be determined were *Calcisphæræ*, and of these there were a considerable number, well preserved. The spaces between the granular fragments and organisms were filled in with clean crystalline calcite.

---

* 'Geol. Mag.,' n. s., Vol. iii, Dec. iii, p. 337 (1886).

Section No. 2.—A greyish White Limestone, composed of a spiral shell, foraminifera, polyzoa, and obscure calcareous fragments.

Section No. 3.—From the concretionary bed. The nodules show the same whiteness which is typical of most of the Whitehead Limestone. They occur as large as an inch in diameter, and contain a variety of organic remains, but all badly preserved.

Section No. 4.—From the Whitehead Block. Chiefly made up of dark granular calcareous fragments, with foraminifera and some *Calcisphæræ.*

Comparing the Upper Limestones of the Forest of Dean with the same division in the Bristol area, we find a very considerable difference. In the former district, as I have shown, the upper series are characteristic and well defined, but in the Bristol Coal-field the Middle Limestone simply becomes mixed with grits and argillaceous beds. The " Crease " and " Whitehead " Limestones (as distinct divisions) are not represented.

The Millstone Grit.

Following the " Whitehead Block," we come to from 15 to 20 feet of loose sandy beds and argillaceous flagstones. In some of these I have met with small plant-remains, and, in one instance, with an undoubted shell. These beds pass into yellow sandstone, made up of well-rounded quartz grains, and containing Lepidodendra. This is the base of the true Millstone Grit, which may be said to consist of a loose sandstone of yellow, red and mottled colours, resembling a Triassic sandstone rather than what is understood as Millstone Grit in the South Wales, Bristol and Somersetshire Coal-fields. One of the beds which I have observed near Mitcheldean, and at Sudely, near Coleford, is interesting on account of its great similarity to the Old Red Conglomerate. The typical Old Red Conglomerate of Herefordshire and Gloucestershire contains pebbles, which Sir Henry De la Beche calls " veinstone quartz." * In the bed of Millstone Grit referred to, these same pebbles occur, associated, as in the Old Red Conglomerate, with small quartz grains, the whole being loosely cemented together by a ferruginous siliceous matrix. From this evidence I conclude that the same land must have been undergoing denudation during the time that the particular bed of

---

* 'Mem. Geol. Survey,' Vol. i, p. 64.

Millstone Grit was deposited, as during the deposition of the Old Red Conglomerate.

In the Bristol, Somersetshire, and South Wales Coal-fields the Millstone Grit is a hard, slightly pink quartzite, and therefore differs lithologically from that in the Forest of Dean, but not in actual chemical composition, as the following analyses prove:—

	Bristol (Brandon Hill).	South Wales (Pentyrch).	Forest of Dean (Drybrook).
Silica	97·80	96·63	98·06
Alumina	·47	1·15	·30
Oxide of iron	·80	·70	·50
Lime	·44	·55	·33
Organic matter	·17	·30	·20
Carbonic acid	·39	·20	·30
Moisture	·22	·10	—
Alkalies	—	trace.	trace.
	100·29	99·63	99·69

The Millstone Grit, as in other coal-fields, passes up into the Coal Measures. The lowest seam of coal is that of the Lower Trenchard, 1 foot 2 inches thick. There are in all 20 principal seams, varying from eight inches to between, as in the case of the "Coleford High Delf," four and five feet.

SKETCH OF THE GEOLOGY OF THE FOREST OF DEAN, WITH SPECIAL REFERENCE TO THE LONG EXCURSION.

BY WINTOUR F. GWINNELL, F.R.Met.S., F.A.S.

(*Read July 6th*, 1888).

(*Abstract.*)

The Royal Forest of Dean is included in the triangular area between the lower courses of the rivers Severn and Wye. Formerly it included all this area as far north as the parallel of Ross and Newent, but the present area of the Government lands is only about half of this, or nearly 36 square miles. For the purposes of the Long Excursion it is convenient to return to it its old historical and privileged limits, so far, at least, as to include the celebrated Rhætic section of Westbury-on-Severn, and the exposure of Lower Palæozoic rocks at May Hill.

The small district considered is a *multum in parvo*, for all the British systems and most of the formations from Cambrian to Jurassic occur in its limited area, and fine exposures of most of them are common both in the " scarped cliff and quarried stone."

Igneous intrusions and considerable metamorphism are almost absent, but faults are not infrequent, and one in particular extends for a long distance, with a general strike from north to south, and is accompanied by very striking changes both in the geology and in the scenery. The upthrow on the western side must be many thousands of feet, and causes Old Red Sandstone, Silurian and possibly even Cambrian strata to abut, mostly with a considerable dip to the west, against Triassic strata with a gentle dip to the east.

It will be well before separately describing the Rhætic, the Silurian, and the Carboniferous areas to be successively visited, to give, for convenience of reference, a list with approximate thicknesses of the formations exposed, adding the letters of reference used in the maps of the Geological Survey.

		Feet.
	Alluvium.	
*g*1.	Lower Lias	
fg.	Rhætic or Penarth beds, about	50
*f*6.	Keuper " Marls," and Sandstone	about 1000
*f*5.	Keuper " Waterstones "	
e.	Permian (present slightly farther north)	
*d*5.	Coal Measures	2765
*d*4.	Millstone Grit	450

		Feet.
*d*2.	Carboniferous Limestone	480
*d*1.	Lower Limestone Shales	165
c.	Old Red Sandstone	8000 to 10000
	Ledbury Shales (passage beds)	300
*b*7.	Upper Ludlow beds	140
	Aymestry Limestone	30
	Lower Ludlow beds	700
*b*6.	Wenlock Limestone	280
	Wenlock Shale	640
	Woolhope Limestone	150
*b*5.	Upper Llandovery or May Hill Sandstone	
a.	Cambrian (doubtfully present)	

(The thicknesses of the Silurian beds are taken from the neighbouring Malvern area.)

Economic Products and Minerals.

Coal, of excellent quality, estimated by Prof. Hull at 842 millions of tons, of which a third part has been removed or wasted, is found in 31 seams in the Coal Measures, of which eight only range from two to five feet in thickness and are worth working.

Hæmatite, excellent for steel-making owing to its freedom from phosphorus, occurs in the Crease Limestone, and to a smaller extent in the underlying Middle Limestone of the northern portion of the Carboniferous area. Part is smelted at Cinderford, but the bulk is now sent to the Dowlais Works in South Wales.

Clay Ironstone occurs in the shales at almost every colliery, but is nowhere workable at a profit.

Red Ochre abounds at a few localities, and may be seen, conspicuous from afar, covering the miner as he returns from his daily toil "raddled all over."

Iron pyrites, mundic, or "dogs" is abundant in the "Twenty-inch Vein" of coal, and entails serious expense in cutting it out. The supply is scarcely sufficient for its utilization in vitriol-making. Its too frequent presence in joint-planes of the coal diminishes the commercial value of the coal, and renders it ill-suited for gas-making, owing to the great amount of gaseous sulphur-compounds generated; and also explains, perhaps, why coke for the blast-furnaces is now imported from South Wales.

A little argentiferous *Galena* occurs in the lowest coal-seam.

Pyrite, Marcasite, Mispickel, and *Chalcopyrite* all occur in the bone-beds of the Westbury section.

Quartz is found with the ironstone, and, as may be expected, is usually ferruginous, often rose-red.

Selenite is common in the clays and shales, and *Celestine* may be found in the New Red Marl.

Gypsum is found in veins and pockets in the limestone, especially in the ‘ crease.”

Calcite and *Dolomite* occur in beautiful nests of crystals sparkling brilliantly in the labyrinthine caverns of the iron-workings, and are often to be seen above ground in the refuse-heaps around the “ mine pits.”

An excellent *Fireclay*, 20 feet thick, occurs just below the lowest seam of coal, being indeed its “ underclay.”

Other important sources of mineral wealth are the *Sandstones* and *Limestones*, the latter often much dolomitized and occasionally quite crystalline.

The Carboniferous Limestones are known from their colour as “ bluestone ” (Lower), “ redstone ” (Middle), and “ whitehead ” (Upper), the latter lying next above the “crease,” and being often as white as alabaster. They are rarely fit for building except of the roughest class, and where dolomitized not well suited for lime.

The fine-grained and very durable sandstones, in part of Pennant Grit age, which occur intercalated with the coal-seams and shales, are of great thickness (several beds about 100 feet each) and of exceptional quality and repute for building.

The Millstone Grit and the Old Red Conglomerate beds may often be seen in use for building rough walls and for road-metal.

Newnham and Westbury.

Newnham-on-Severn lies on Keuper Sandstone and hard red and grey marls, well seen in the lofty cliff on which rests the church, and in the railway-cuttings on either side of the station. Carbonate of lime is nearly absent in these marls, and apparently fossils are so also ; but resting on the similar marls of the Garden Cliff at Westbury lie the celebrated Rhætic beds. (See the section, fig. 2, *infra*, p. 546).

Though true passage beds between the probably lacustrine red marls and the certainly marine Liassic strata, they form a striking contrast to both in colour, material, and fossils. About 70 feet of strata are exposed, of which about 50 feet may be considered Rhætic, if there be included the unfossiliferous white and grey marls below the Avicula-contorta zone, as well as the whole of the White Lias below the Ammonites-planorbis zone. Thus the section will include :—

	Feet.
e. Lower Lias (Zones of *Ammonites planorbis* and *Ostrea liassica*)	
d. White Lias	15
c. Rhætic Shales (Zone of *Avicula contorta*)	17
b. Rhætic marls, grey, occasionally stained red	17
a. Keuper marls, red, white, and grey	

The two lower series are here quite unfossiliferous, though at Watchet were found teeth of *Microlestes*, the oldest known British mammal. The marls are capped by a thin band (1in.) with fish-scales, teeth, and coprolites. Dark grey shales (15in.) follow; and then a sandy layer (5in.), which is the first bone bed, with casts of shells, *Pullastra arenicola, Avicula contorta*, and fish bones and coprolites. This is the "Micaceous bone bed." After two feet of black shales comes the "Pullastra bed," a hard, sandy, ripple-marked bed (1ft.) which stands out as a ledge from the cliff. On it worm-casts and rain-pittings may be seen with the ripples, and, of course, show it to be a shore deposit. *Cardium rhæticum* and *Modiola minima* first occur here. Black shales (18in.) succeed, and then the "Great Bone bed," a bone-breccia, black with shining fish-scales, fin-spines, and teeth and vertebræ of fishes and Saurian reptiles, or golden with brilliant pyrites and other metallic sulphides. It is really double, consisting of two thin layers (each 1in.), separated by six inches of shale. The succeeding black shales (7ft.) consist of paper-like laminæ, full of *Cardium rhæticum*, and having two or three thin bone-beds. Following these "Cardium shales" come similar "Avicula shales" (2ft. 6in.), full of *Avicula contorta;* and then the "Lower and Upper Pecten beds" (2ft., including the intermediate shales), containing large flat valves of *Pecten valoniensis*, and the other usual Rhætic mollusca. Grey marls (7ft.) commence the Upper Rhætic, and form a contrast to the underlying black shales. The pale, hard, irregularly-bedded "Estheria bed" (18in.), occasionally with nests of the minute bivalve crustacean *Estheria*, forms a second conspicuous ledge on the cliff. Clays and then Marls follow (6ft.), with fish-remains in the latter.

"White Lias Limestone" (placed by Etheridge at the base of the Lias proper) forms a third ledge. It consists of a thin band 2in.), composed entirely of *Modiola minima* and *Pleuromya dunkeri*, on which rests the "Monotis bed" (3in.), equally full of the small but beautiful valves of the Aviculid, *Monotis decussata.* The oyster so characteristic of the bottom beds of the Lias, *Ostrea liassica,* also occurs, and the wing of a dragon-fly was found. Pale paper-like shales (18in.), with fish-remains, separate this Lower from an Upper Limestone (3in.), full of *Modiola minima* and *Ostrea liassica.*

True Lower Lias Clays and Limestone, belonging to the zone of *Ammonites planorbis,* complete the section, but are not well exposed.

May Hill.

May Hill, having Huntley and Blaisdon Hills to the south, lies about 10 miles south of the Malvern Range, and the same distance both from the northern extremity of the Tortworth district and from the heart of the Woolhope Valley of elevation. Each of these four districts consists chiefly of an inlier of Upper Silurian strata, rising from beneath Old Red Sandstone on the west, and with or without older rocks beneath, all faulted against Mesozoic strata on the east, except in the Woolhope inlier or pericline, which is quite surrounded by Old Red, though but a mile of it separates the Ludlow beds of this and the May Hill inlier. The latter extends about six miles by 2½, and rises in the fir-clad summit of May Hill to 973 feet in elevation. The lowest visible rock is "a hard, siliceous, close-grained, dark-grey schistose stone, with quartz-veins, and is quarried for the use of the roads. It has all the aspect of the Cambrian rocks of the Longmynd; and containing no fossils, and being much broken and contorted, has no visible connection with the overlying sandstones and shale, in none of which are there any traces of either the Llandeilo or Caradoc formations, or even of the Lower Llandovery rocks." ('Siluria,' Chap. V.) There follow purplish and green shales and sands, passing up into grits and sandstones, with abundant Upper Llandovery fossils—*Pentamerus lens, P. liratus, Orthis calligramma, Atrypa hemispherica, A. reticularis.* At Dursley Cross and on the W. flank of May Hill this Pentamerus bed is seen to pass into the Woolhope Limestone, which here consists of calcareous nodules and irregular courses, disseminated in the lower part of the Wenlock shale. This latter formation lies in the hollow between Huntley and May Hills, and also forms the western base of the latter. The crest of the former is formed by Wenlock Limestone, which protrudes as a long ridge, dipping west. Wenlock fossils are abundant —Corals, Euomphali, Trilobites, and especially Brachiopods. The overlying Ludlow beds form the west flank of Huntley Hill, and near the centre are harder and slightly calcareous, this part representing the Aymestry Limestone. Beneath the stream and the railway probably lie the passage beds to the Old Red (the Downton Sandstone and Ledbury Shales), but here they are neither so well developed nor so well exposed as they are at Ledbury, 10 miles further north. A fault closely follows the line of railway at Longhope.

The Carboniferous area.

The feature of most geological interest in the Forest of Dean is the central centroclinal of Carboniferous strata, an outlier of the great South Wales Coal-field, and the most perfect basin in our islands, since the strata dip from the margin towards the centre everywhere, save in one small part on the west side. From a horizontal position over the centre of the basin, near the Speech House, the beds rise rapidly to the eastern edge, ending there in steep escarpments of 600 to 800 feet in elevation, and, of course, with narrow outcrops. To the north, and still more to the west, the lower beds spread out considerably, and the limestones in particular are grandly exposed in the picturesque cliffs overlooking the Wye, forming, indeed, the upper and lower gorges so well seen respectively from Symonds' Yat (500ft.) and the Windcliff (900ft.). The strata in these are but little inclined. The Carboniferous series below the Coal Measures have been described by Mr. Wethered.[*] The following gives the succession of beds in this formation :—

Coal Measures.

	Ft.	In.
Sandstones and shales with several thin coals, about	1,000	0
Dog delf seam of coal	1	4
Blue shale	36	0
Smith delf coal	2	6
Blue shale	15	0
Little delf coal	1	4
Blue shale	15	0
Parkend high delf coal or Lowrey	3	0
Blue shale and sandstone	48	0
Starkey delf coals with partings	9	3
Rocky veins with partings of shale	30	0
Hard shale	34	0
Upper Churchway delf coal	2	0

[*] *Vide supra*, pp. 510-521.

	Ft.	In.
Shale and sandstone	50	0
Lower Churchway delf ("No coal")	1	4
Shale	50	0
Braley delf coal	1	4
Sandstone	117	0
Shale and Sandstone	142	0
Yorkley or Nag's Head delf coal	2	6
Sandstone and shale	97	0
Whittington coal	2	10
Sandstone	124	0
Coleford high delf (best seam worked)	4	6
Sandstone	113	0
Upper Trenchard coal	1	4
Stone and shale	67	0
Lower Trenchard, or Bottom coal	1	2
Fire clay	20	0
Farewell rock or Millstone grit.		

The chief seams of coal worked in the Forest are the Parkend, Churchway, Yorkley, Whittington, and Coleford high delf seams. An important feature to note is the entire absence of the dreaded fire-damp,* and as a result the great expense and inconvenience of using safety-lamps is avoided, naked candles stuck in clay holders being everywhere used; though at Trafalgar colliery the electric light is also in use. This is the best pit for a visitor's descent. It lies on the Serridge or watershed, near to the Drybrook Road Station of the Severn and Wye Railway.

Cave Deposits.—In certain caves of the upper gorge of the Wye, especially "King Arthur's Hall" in the Great Doward, facing Symond's Yat, bone-stalagmite and human remains and implements have been found. The succession of deposits in this cave were :—

1. Black earth, with human bones, teeth and bones of beaver and bear, and coarse pottery.
2. Sandy deposit (stratified), four to five feet thick.
3. Floor of stalagmite, two to three feet, under which were abundant mammalian remains — Mammoth, rhinoceros, hyæna, cave lion, cave bear, Irish elk ; also flint knives and scrapers.

---

* The explanation of this unusual and fortunate feature is, it appears to me, that thick porous sandstones overlie most of the coal-seams through which the carburetted hydrogen escapes, instead of accumulating under pressure, as it does where impervious shales form the great mass of the partings, as they do in so many other coal-fields.

NOTES ON THE RHÆTIC BEDS AND LIAS OF GLAMORGANSHIRE.

By HORACE B. WOODWARD, F.G.S., of the Geological Survey of England and Wales.

(Communicated by permission of the Director-General of the Geological Survey.)

(*Read July 6th*, 1888).

It must at all times be a matter of especial interest to study a formation at the locality whence it derives its name; and at Penarth we contemplate the English equivalents of the Rhætic formation to which in 1864 the name Penarth beds was given by Mr. Bristow.* It is, however, not unfrequently the case that at such a locality we do not find the most complete representation of the strata, and Penarth has not attained the fame of several other places as a hunting-ground for the collector of fossils. Each exposure of the strata may indeed exhibit some particular feature of interest. The Bone-bed is best shown at Aust, the *Monotis*-bed at Westbury-on-Severn, the Cotham Marble near Bath, and the White Lias generally in Somerset. Nevertheless, at Penarth, and in the cliffs extending southwards to Lavernock, the Rhætic beds are more clearly and prominently displayed than in any other part of Britain, not even excepting St. Audries and Blue Anchor near Watchet, where the beds attain a greater thickness. It is true that at Penarth Headland itself the beds are inaccessible, except to those who care to climb an almost perpendicular cliff; but observations made on the face of a precipice are not necessary in this case, for Nature has produced undulations that bring the strata to the sea-level at two points as we proceed southwards to Lavernock (Fig. 1).

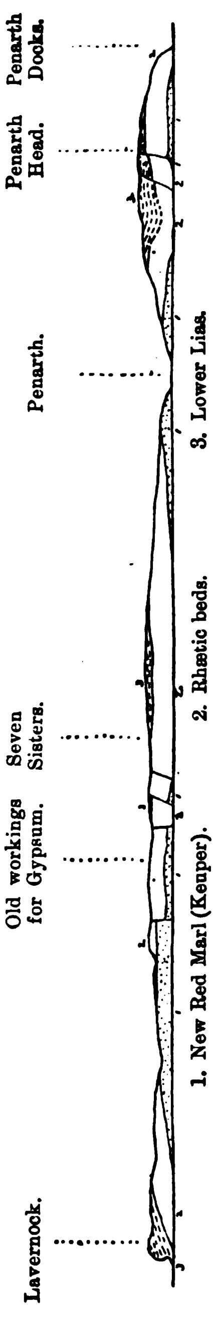
With these advantages, Penarth has not attracted a great deal of attention. The sections were briefly described in 1860 by Dr. Wright,† but it was not until 1864 that a detailed account of the strata was published. This was the joint work of Mr. Bristow and Mr. Etheridge, and it was amplified later on in a series of

---

* 'Geol. Mag.,' Vol. i (1864), p. 236.

† 'Quart. Journ. Geol. Soc.,' Vol. xvi, p. 381.

FIG. 1.—SECTION FROM LAVERNOCK TO PENARTH HEAD.



vertical sections published by the Geological Survey,* and in a paper communicated to the Cardiff Naturalists' Society† in 1871 by Mr. Etheridge.

The Rhætic beds along this coast-line, as in most other localities, present the orthodox three-fold division; but here the uppermost portion consists for the most part of grey marls (12 to 20 feet thick) instead of the hard and compact layers of White Lias which we meet with in Somerset and Dorset. The Black Shales below (from 16 to 22 feet thick) present their ordinary features, yielding *Avicula contorta* and *Cardium rhæticum*, with bands of limestone containing *Pecten valoniensis*, and thin Bone-beds at more than one horizon at and near the base. The grey and tea-green marls (45 to 50 feet thick) are separated from the red and variegated Keuper Marls by a tolerably well-marked and even colour-line. Near the base they contain impersistent bands of gypsum, and exhibit occasional reddish tinges. On the whole these Grey Marls form a conspicuous division; but their interest is mainly stratigraphical, for no fossils have been observed in them at Penarth, although Fish-remains and even Mollusca have been found at some localities, and they are noted at Watchet for the tooth of *Microlestes* obtained by Professor Boyd Dawkins.

An interesting feature in connection with these beds is that noticed by Mr. John Storrie.‡ He observed that traces of a Bone-bed occur in patches in the hollows of the earthy limestone that caps the Grey Marl division. Apparently similar features were noticed by Mr. J. E. Lee, on the banks of the Severn, at Gold Cliff, near Newport; and he attributed the hollows to the action of "rills of running water on the marls previously to the deposit of the Bone-bed." * Again, at Cadoxton, west of Lavernock, relics of a Bone-bed occur in crevices of the top bed of marl at the base of the Black Shales. My attention was first drawn to this feature by Dr. A. Geikie, who, when on a visit to the cliffs near Axmouth in 1885, noticed that remains of the Bone-bed filled cracks in the green marl at the base of the Black Shales, as if this fossiliferous layer had been deposited on a sun-dried and fissured surface of the Marl. Subsequently I observed a similar case near Watchet; and these instances point to local pauses in the accumulation of sediment. The subject, however, is by no means new, for I find that many years ago Mr. H. E. Strickland, in describing the Bone-bed at Combe Hill, near Cheltenham, remarked that "the osseous fragments have the appearance of having been washed into the hollows of a rippled surface of clay."† In this instance the Bone-bed occurred two or three feet above the base of the Black Shales.

---

* Sheet 47.

† Vol. iii, p. 39.

‡ 'Trans. Cardiff Nat. Soc.,' Vol. xiv, p. 100 (1883).

It is well known that the Rhætic Beds are not free from those diversities of geological opinion that add much zest to the pursuit of the science. Some observers would separate the White Lias from the Rhætic beds, and include that portion with the zone of *Ammonites planorbis* at the base of the Lias. Others would divorce the Grey Marls and place them with the Keuper. If we adopt these views we should have only the Black Shales left, and although they form the most characteristic portion of the Rhætic series, they are absent near Rugby and at one or two other localities, where there is no evidence otherwise of a break in the sequence of strata. No argument, however, can be founded on such a consideration beyond the very natural one that the formation, so restricted, would not be sufficiently important to merit a separate designation. But the arguments for severing the White Lias on the one hand and the Grey Marls on the other are based on local and limited evidence. Everyone admits that the Rhætic Beds form a passage between the Triassic and Jurassic systems; and this being the case, it is natural that in some localities the beds are more intimately connected with the Keuper Marls and at others with the lower limestones of the Lias.

---

* 'Rep. Brit. Assoc. for 1872,' Sections, p. 116. (See p. 538.)

† 'Proc. Geol. Soc.,' Vol. iii, p. 585.

Between Axmouth and Lyme Regis, and again near Watchet, the Grey Marls comprise bands of very dark grey, and even black, marly clays, that foreshadow the Black Shales that succeeded them. At the latter locality, indeed, we hardly know where to draw the line between the Black Shales and the Grey Marls beneath them; while at Penarth we find the Black Shales overlaid by another division of grey marls and shales that lithologically resemble the underlying marls. Moreover, the lower Grey Marls, and even the Red Marls in places, contain bands of compact, more or less earthy limestone, that could not be distinguished lithologically from beds of White Lias. These facts show the intimate connection of the series of beds in their sedimentary characters; and while we may admit that at Axmouth and Watchet the Grey Marls present an aspect that would lead us to link them with the superincumbent Rhætic beds and Lias; in other localities, as at Bitton and Bath, and at Wainlode, near Tewkesbury, their characters approach more nearly to those of the Keuper Marls.

Passing upwards to the Lias we find a difficulty at Penarth in fixing the precise boundary between these strata and the Rhætic beds. But where Nature has made no marked line of demarcation, it is perhaps needless for us to be concerned about the matter. The Grey Marls that occur above the Black Shales represent the White Lias of other localities, and, in fact, we find some layers of White Lias in this division at Penarth, together with a band that reminds us of the Cotham Stone. The fossils include species of *Ostrea, Modiola, Pleurophorus*, &c., for the most part poorly preserved, as the fossils usually are in this portion of the Rhætic series. On top of these Marls there is a bed of dark-grey and brown paper-shales, from one to two feet thick, that forms what may be termed the debatable ground between the Rhætic beds and the Lias. I should prefer to group it with the Lias, because a similar bed is found in many localities on top of the White Lias, and in situations where it clearly belongs to the Lower Lias. At Penarth itself we cannot decide the matter, for the fossils *Ostrea liassica* and *Modiola minima* are common to the Rhætic beds and to Lower Lias.

Resting on these paper-shales we find a series of even-bedded argillaceous limestones and clays yielding the *Ostrea* and *Modiola* in abundance, especially the former, so that they constitute the "Ostrea-beds" of some authorities—here 12 or 15 feet thick. These merge upwards into similar beds that contain many specimens of *Ammonites planorbis*, so that the mass of the Lias above the Rhætic beds, for 35 or 40 feet, belongs to the zone of *Ammonites planorbis*. These beds cap the headland of Penarth, and are well shown at Lavernock point where they dip sea-ward; but rounding this headland towards the west we find the limestones paving the foreshore (where they exhibit their fossil treasures) and dipping westwards for a space, when they again rise, forming, in fact, a gentle synclinal. The trough of this is filled with a third series of Grey Marls, not unlike those of the Rhætic beds, and I was at first much puzzled with them when examining a section on the new railway near Lavernock. These marls and marly clays, with indurated bands, about 40 feet thick, are overlaid by 25 feet of limestones and clays. Unfortunately the upper part of the cliff west of Lavernock is not very accessible, and, as no fossils rewarded my labours, I could only infer that these marls and overlying limestones marked, in all probability, the lower portion of the zones of *Ammonites angulatus* and *A. bucklandi*—zones which are, to some extent, represented at Penarth, and are so well developed further westwards along the Glamorganshire coast. The cliffs along this further portion of the land are well worth a visit.

Passing Sully, we are reminded of Conybeare, who was Rector from 1823 to 1836; and only last year I met two somewhat elderly men who had pleasant recollections of him and his geological explorations.

We pass Barry Island, whose beauties, alas! are now sadly marred by the engineering operations for the new docks—works which practically unite this tract with the mainland.

Onwards past Porthkerry we come to a series of Lias cliffs that extend, with some interruptions at Aberthaw, to Dunraven and Southerndown, near the mouth of the Ogmore. These cliffs exhibit, perhaps, the finest exposure of the Lower Lias Limestones in this country. We have not the complete sequence of Lias visible at Lyme Regis and Charmouth in Dorsetshire; but here in South Wales the zones of *Ammonites angulatus* and *A. bucklandi* (taken together) are much more fully and continuously exposed. It is true that 14 miles of cliffs showing the same set of beds, dislocated here and there by faults, seem a little monotonous; and as fossils are neither very varied nor very abundant, we cannot wonder that the cliffs for the greater part of the distance are but little visited by the geologist. At any rate, the observations recorded are meagre in the extreme, for they amount to such brief references that I was unaware, until I reached the spot, that the celebrated "Aberthaw lime" was obtained from beach-boulders and not procured from the rock *in situ.* It may be mentioned that many beds of limestone in the neighbouring cliffs are much jointed; hence they break up into small masses, which are readily rounded by the action of the sea.

The cliffs exhibit a series of argillaceous limestones, shales and marls, which must attain a thickness of nigh 200 feet, and for great part of the way the limestones stand out also in ledges and platforms along the foreshore, so that our progress along these natural pavements is a very happy one, excepting where it is diversified by faults modifying the strike of the ledges, or by heaps of boulder-shingle that lie here and there on the surfaces of the platforms.

It is very instructive to observe the distribution of the fossils, for we have the Lias well exposed both in plan and in section, and may notice how the organic remains occur in groups or colonies, abundant now and again at various levels. We can picture the evidence obtained in a quarry, where a *Pentacrinite*-bed, a *Gryphæa*-bed, and a *Lima*-bed might be noted in succession; but here on the foreshore we may observe groups of these fossils, sometimes in family clusters, at others intermingled, and at many different horizons, while the same bed appears quite unfossiliferous over the greater portion of its exposure. Such evidence warns us not to place too great reliance on the persistency of fossil-beds, and it explains why organic remains abundant at a certain locality at one time, have become rare later on, when the beds have been extensively worked.

On the whole this great series of limestones is singularly barren, but this appears to be the rule with strata that are thickly developed. Compare, for instance, these rocks with the attenuated Lias near Radstock; or the thick beds of Inferior Oolite near Cheltenham, with their very fossiliferous but scantily-developed equivalents in Dorsetshire.

When we approach Dunraven we come to the confines of a very debatable tract of Lias—a district that has been much visited by geologists, and much written about also. We come, in fact, to an altered condition of the Lower Lias, not necessarily an "abnormal" condition, as it has been termed, but to a tract where the beds were deposited under different sedimentary conditions, and in a tolerably distinct zoological province. We have, in fact, marginal deposits, to which the term Lias-conglomerate was appropriately given by Sir Henry De la Beche. It will be unnecessary here to give all the views of different geologists on the age and relations of these beds, but it may be observed that from Dunraven onwards to Southerndown and Sutton we find the ordinary beds of Lower Lias limestone and shale resting conformably on a series of bluish-grey conglomeratic limestones, termed the Southerndown beds, that pass downwards into pale, more or less tufaceous limestones and conglomerates, known as the Sutton stone and Conglomerate.

The whole of this conglomeratic series was in 1866 claimed as Rhætic by Mr. E. B. Tawney, but his view was shortly afterwards contested by Mr. Bristow, Mr. Charles Moore, and Prof. Tate, who maintained that the beds were truly a portion of the Lower Lias. As regards their precise palæontological equivalents opinions still differ, for it is questioned whether they represent the zone of *Ammonites planorbis* or that of *A. angulatus ;* while Dr. Duncan, who included the White Lias and the zone of *A. planorbis* under the term Infra-Lias, applied this vague term to the conglomeratic beds of Sutton and Southerndown. Ultimately Mr. Tawney relinquished his view of the Rhætic age of these beds, and the question seemed settled for a time.

Mr. Etheridge, however, remained in a state of uncertainty, for in his paper on the Penarth beds (before mentioned) he observed that the precise position of the Sutton stone was still an open question, while in 1884 Mr. R. F. Tomes, who had many years before written about the beds, returned to the discussion of the subject,* and, in company with Mr. W. C. Lucy,† maintained that the Sutton stone was the equivalent of the White Lias.

In order to thoroughly understand the stratigraphical relations of the beds, much time (and so far as my own experience goes, at least ten days) must be devoted to the cliff-sections, which in the area under dispute extend only a distance of about two miles. But

* 'Quart. Journ. Geol. Soc.,' Vol. xl, p. 353.
† 'Proc. Cotteswold Club,' Vol. viii, p. 254.

much of the cliffs can only be examined at low spring-tides, and by scrambling over ragged rocks. It is necessary to note the beds in detail at every available point, and it is then manifest that the bluish-conglomeratic (Southerndown) beds increase in thickness as we proceed from Dunraven towards Sutton, but they shade downwards into the White Sutton stone and conglomerate without any line of demarcation. The beds, moreover, are faulted in several places, and in positions which render exact measurements of the beds most difficult.

It is, however, clear that the White Sutton stone and Conglomerate form the base of the series, resting irregularly, and in hollows, on the upturned edges of the Carboniferous Limestone, so that the thickness varies considerably at different points, from 25 to 40 feet. Commencing west of Southerndown, these beds may be traced from Sutton to the cliffs at Pant-y-Slade, near West, where they are overlaid by a considerable thickness of blue conglomeratic limestones; thence they descend to the sea-level by the large Fairy Cavern. Here three faults affect the beds; and the White Sutton stone is repeated in one instance on the foreshore, but is carried out of sight beneath the main mass of the Southerndown Cliffs. There the bluish conglomeratic limestones are exposed at the base of the cliffs and on the foreshore below the ordinary beds of Lower Lias. As we proceed towards Dunraven Castle, higher and higher beds of the Lias are exposed in the cliffs, and then again we meet with a considerable fault which brings up the Sutton stone and Conglomerate, and the Carboniferous Limestone, in the headland known as the Witches Point, Dunraven. Thence round to the little bay south of Dunraven Castle, we may trace the sequence again of Carboniferous Limestone, covered irregularly by White Sutton stone and Conglomerate (passing horizontally into greyish and bluish-grey beds in places), and overlaid by the more conspicuously blue conglomeratic limestones (Southerndown beds), above which come the ordinary beds of Lias Limestone and Shale.

These ordinary beds of Lower Lias, which extend along the cliffs before noted to near Barry Island, clearly belong to the zones of *Ammonites bucklandi* and *A. angulatus*, yielding these fossils, together with *Gryphæa incurva*, *Lima gigantea*, *Pentacrinites*, etc. The only specimens of *A. angulatus* which I obtained came from the base of this series near Dunraven, but Mr. Moore notes it from the conglomeratic beds below, together with *Lima gigantea*, *Ostrea* *liassica*, several gasteropods, and other fossils. There can be no question, therefore, of their Liassic age. With regard to the Sutton stone, fossils are by no means so abundant, but it is noteworthy that two species of *Ammonites* were described by Mr. Tawney, one resembling *A. johnstoni*, but both so poorly preserved that opinions differed on their identification. These specimens (and one also of *A. angulatus* recorded by Mr. Moore) were taken from the upper portion of the Sutton Series, 18 to 30 feet above their base. Hence the beds at this horizon may be regarded as representing the limestones with *A. planorbis* at Penarth, or at any rate the upper portion of that zone where it passes into the zone of *A. angulatus*.

The stone at Sutton yields more especially *Ostrea multicostata*, *O. intusstriata*, *Pecten suttonensis* or *P. pollux*, and *Cardinia suttonensis*, as well as numerous corals. The corals were most of them new to this country. They are, however, many of them, known from the so-called Infra-Lias of the continent, but do not help us in our comparisons of the strata with other English beds.

The other fossils present a Liassic rather than a Rhætic facies, and lead us to group the mass of Sutton stone with the "Ostrea-beds" before noted at Penarth, which form the lower part of the zone of *Ammonites planorbis*.

Oysters are somewhat troublesome forms to deal with, especially in the fossil state, and the authorities have differed much in their identification of the Sutton species, but *Ostrea liassica* has been recorded, together with other species by Mr. Moore. I may mention that I have found *Ostrea multicostata* and *Cardinia suttonensis*, two of the most abundant fossils of the Sutton stone, in the same beds of Lower Lias, together with *Ammonites planorbis* and *A. johnstoni*. The locality was Harptree, on the Mendip Hills, and here the Lower Lias presents some remarkable cherty modifications.

It is unnecessary to enter further into this subject. The suggestion that the Sutton stone represents the White Lias appears to have been based to some extent on a lithological resemblance, perhaps mainly on the fact that the beds are pale, for the texture of the Sutton stone differs considerably from the ordinary beds of White Lias.

When we remember that at Penarth the upper portion of the Rhætic series consists mainly of grey marls, and when we see it at

Stormy Down, near Bridgend, to comprise only one or two bands of compact white limestone, there is no sufficient reason to regard the 30 or 40 feet of White Sutton stone as Rhætic on the ground that it consists of pale beds at the base of the Lias.

At Stormy Down there is a thin conglomeratic band at the base of the Lias Limestones, which there belong to the zone of *Ammonites planorbis*, and this band occurs on top of the beds that are admitted to represent the White Lias. It has been taken to correspond in a feeble way with the Sutton Conglomerate. There is no reason to dispute this, but a conglomeratic band suggesting a local change in conditions should be grouped rather with the overlying than with the underlying beds, and hence we need not hesitate to place it and the Sutton stone also in the Lower Lias. The peculiar characters of the Sutton stone may be due to its being derived largely from islets of Carboniferous Limestone, and to the limestone-mud being mixed to some extent with the *débris* of corals.

NOTE.—Since writing the above (see p. 531), I have had the opportunity of visiting Goldcliff, in Monmouthshire, and of seeing the Bone-bed described by Mr. Lee. (See also his 'Note-book of an Amateur Geologist,' 1881, p. 72, and plates 171 and 172. He, however, omitted to point out that the Bone-bed there occurs beneath three feet of the greenish-grey marls, which are thus shown to be intimately linked with the *Avicula-contorta* Shales above.—H. B. W.]

NOTE ON THE SOUTH WALES COAL-FIELD.

By F. W. RUDLER, F.G.S., President.

During the approaching visit of the Association to South Wales exceptional facilities will be offered for making an Excursion into the heart of this coal-field, under the able guidance of Mr. William Galloway, of Cardiff. To those who are about to avail themselves of this opportunity, it may be useful to possess a general sketch of the physical characters and geological structure of the district about to be visited.

While occupying the greater part of Glamorganshire, the coal-field of South Wales stretches to a greater or less extent into the four neighbouring counties of Monmouth, Brecknock, Carmarthen, and Pembroke. As seen on a geological map the Coal-measures occupy an irregular oval or pear-shaped area, having its longest axis in an east and west direction, and tapering towards the west. The southern margin of the field is deeply indented by Swansea Bay, while further to the west it is so completely cut into by the waters of Carmarthen Bay that the western portion is severed from the main area, and thus forms the isolated coal-field of Pembrokeshire.

The extreme length of the larger portion, measured from Pontypool in the east, to Kidwelly in the west, is about 56 miles; while the greatest length of the Pembrokeshire area is 17 miles. The maximum width of the large field, not far from the meridian of Cardiff, is nearly 20 miles. The total area of the coal-field, though variously estimated, may be set down at about 950 square miles; it is thus, with the exception of the Clyde basin, the largest coal-bearing tract in Britain.

The Coal-measures of South Wales form a true basin, the dip being everywhere from the margin inwards. Along the southern border the dip is greater than along the northern outcrop; but the beds near the southern edge, after plunging inwards, at varying angles up to 30° or 40°, are soon elevated, and fortunately brought within easy reach of the miner by means of a great anticlinal ridge, which traversing the field in an east and west direction, may be traced, more or less continuously, from Risca through Maesteg to near Aberafon. The effect of this elevation is to divide the coal-basin into two elongated troughs; and since the axis of upheaval is much nearer to the southern edge of the field than to the north, it follows that the southern trough is narrower than its northern neighbour. It should be noted that the field is also disturbed by other anticlinals of subordinate magnitude and by numerous faults. The faults run chiefly from north-north-west to south-south-east, and have in some instances a downthrow of as much as 300 yards.

The Coal-field is traversed by a succession of narrow deep valleys, running generally in a north and south direction, and corresponding in many cases with lines of dislocation. Much of the field may be regarded as a plateau of Coal-measures deeply trenched by picturesque valleys, between which are tabular hills and rugged heights of sandstone. The highest ground is Carn-fach, to the south-west of Hirwain, in Glamorganshire, which rises to an altitude of 1,971 feet above sea-level. It is naturally in the valleys that most of the great industrial centres are situated. The principal of these parallel valleys are those of the Nedd, the Afon, the Ogwr, the Taff, the Rhymney, and the Ebbw, with their tributaries. Rapid streams, flowing into the Bristol Channel, run through most of the valleys. On an alluvial tract, at the mouth of the Taff Vale, Cardiff is situated, and it is up this valley, and its tributary the Rhondda, that the Association will make its Excursion.

These transverse valleys by cutting deep into the Coal-measures offer unusual facilities for winning the mineral, and for effecting its transport by railway and canal. Valuable coal-seams cropping out on the sides of the valleys long ago invited the miner to work them by open quarry, or tempted him to follow them by driving his adit into the hill-side. Documentary evidence exists to show that the coal of this area had attracted attention some three centuries ago, though the resources of the field remained practically undeveloped until pit-coal came to supersede charcoal in iron smelting. The steam-coal trade—an industry of first importance in the district—is a development of the last half-century.

The coal-field of South Wales is almost encircled by a belt of Carboniferous Limestone. On the north this limestone rises into hills upwards of 1,200 feet high, forming mural escarpments overlooking the Old Red Sandstone; while in the south the scenery is less bold and the hills rarely reach an elevation of 500 feet. In the latter region the older rocks are, to a large extent, concealed by coverings of Dolomitic Conglomerate and Lias, and also by Glacial Drift. In the eastern part of the field the Coal-measures rest upon Millstone Grit, but to the west of Swansea Bay this formation disappears, and the lower measures repose on Carboniferous Limestone, while at Haverfordwest this, in turn, is lost, and the Coal-measures are based directly upon Lower Silurian (Ordovician) strata.

The vertical thickness of the Coal-measures varies in the different valleys, but the maximum has been estimated at from 7,000 to 10,000 feet. At the base of the Coal-measures is the "Farewell Rock," a marine sandstone, associated by some writers with the Millstone Grit. The Lower Coal-Measures—known sometimes as the "White Ash series" and the "Lower Shale series"—contain not only the most valuable seams of steam-coal, but the principal bands of clay-ironstone. Seams of workable coal, reaching in some cases a thickness of upwards of nine feet, and extending with remarkable persistence over a wide area, are so numerous as to form an aggregate of about 50 feet.

Above the lower division of the Coal-measures is the "Pennant series," a group of beds containing steam-coal of fair quality, with black-band ironstone, but on the whole less remarkable for its mineral wealth. The inferior beds of the Pennant series, immediately overlying the Lower Shale group, are sandstones passing into a siliceous conglomerate known locally as the "Cockshoot rock." The upper series of Coal-measures has suffered great denudation, but valuable relics have been preserved, and the famous Mynyddysllwyn seam, which yielded a household coal of great value, now almost exhausted, occurs low down in this series.

One of the most noteworthy features in the coals of South Wales is the change which they suffer with respect to their bituminous character in passing across the field from east to west. Speaking in broad terms, it may be said that coal of normal character may be found in the south-east, this bituminous fuel being suitable for household purposes, and yielding "smalls" that readily coke. Towards the centre of the field the coal becomes less bituminous, passing into a "dry" or non-coking coal, free burning yet practically smokeless, and known as semi-bituminous or "steam-coal." Finally this merges in the north and west into true anthracite or "stone-coal."*

It has often been supposed that this change is due to the proximity of some igneous rock, which has effected a kind of natural distillation of the neighbouring coal. In Pembrokeshire, where the seams are much contorted and faulted, coal is occasionally found "burnt" in the vicinity of the trappean intrusions. But by far the larger part of the South Wales coal-field is remarkably free from such disturbances; nor is there reason to believe that any large masses of igneous rock are concealed at moderate distances below. Mr. Galloway, our Director, has suggested, with much probability, that the change may have been brought about by a gradual rise of temperature towards the north-west, connected with the thickening of the strata in that direction. He assumes that originally the coal-seams in the north-west of the field were covered by a much greater thickness of beds than in the south-east, and being thus buried deeper beneath the surface they must have been exposed to a higher temperature, which would tend to induce more or less complete de-bituminization of the coal.

---

* George Owen, of Henllys, who wrote a description of the South Wales coal-field in the latter part of the sixteenth century, quaintly describes the Welsh anthracite as a coal which "being once kindled giveth a greater heat than light, and delighteth to burn in dark places." Moreover, it "is not noysome for the smoake nor nothing soe lothsome for the smell as the ring cole is, whose smoake annoyeth all things neare it, as fyne linen, men's handes that warm themselves by it; but this stone cole yieldeth in a manner noe smoake after it is kindled, and is soe pure that fine camerick and laune is usually dried by it without any stayne or blemish, and is a most proved good dryer of malt—therein passing wood, ferne, or straw." This essay by George Owen was described by Buckland and Conybeare as "a work of the highest interest, as being the earliest example extant in any language of what can properly be called geological investigation."—'Trans. Geol. Soc.,' Ser. ii, Vol. i, p. 312.

EXCURSION TO THE FOREST OF DEAN, WYE VALLEY, AND SOUTH WALES.

MONDAY, AUGUST 6TH, TO SATURDAY, AUGUST 11TH.

Directors: THE PRESIDENT; WILLIAM GALLOWAY, of Cardiff; W. F. GWINNELL, F.R.Met. S.; J. STORRIE, Curator of the Cardiff Museum; T. H. THOMAS, R.C.A., President of the Cardiff Naturalists' Society; DR. C. T. VACHELL, of Cardiff; and E. WETHERED, F.G.S., F.C.S., F.R.M.S., Hon. Sec. Cotteswold Naturalists' Field Club and Cheltenham Nat. Hist. Soc.

(*Report by* THE DIRECTORS.)

Monday.—Gloucester had been chosen as a convenient centre for the work to be undertaken on Monday and Tuesday, and here the party was met, early on Monday morning, by Mr. Wethered, who acted as Director during the day. From Gloucester the train was taken, on the Ross and Hereford line, to Mitcheldean Road, at the extreme north-eastern corner of the Forest of Dean. A move was at once made in the direction of Baily Hill, and on the way thither an exposure of Old Red Conglomerate was seen. The Director here called a halt for the purpose of explaining the structure of the surrounding country. He pointed out the features of the Old Red Conglomerate, which, he remarked, pointed to an alteration of the conditions which had allowed of the deposition of the Old Red Sandstone beneath, and to a coming change which brought in the Carboniferous rocks. For this reason he asked them to mark well this Conglomerate, as he regarded it as the upper limit of the Old Red and Devonian rocks of the west of England. The beds which intervened between it and the true Carboniferous strata were, in his opinion, transitional, and should be so regarded.

Some old Roman workings for iron ore were then visited, which had been excavated in the Carboniferous Limestone.

Baily Hill Quarry was the next place of interest in the programme. It is opened in the Carboniferous Limestone, which appears to be all dolomitized. Proceeding further, across the dip of the strata, the Lower Limestone Shales were seen in two quarries. The Director described the features of the beds and also the chief fossils which occur in them.

The "deep cutting" on the road from Drybrook to Ross was then visited. Here the Transition Beds, *i.e.*, those between the Old Red Conglomerate and Lower Limestone Shales, are very well exposed. There is certainly no better exposure in the west of England. The many-coloured sandy beds and green shales which constitute this series were traced from the Lower Limestone Shales to the Old Red Conglomerate.

After luncheon at a wayside inn, another quarry opening in the dolomitized Carboniferous Limestone was visited, and then some exposures of the Upper Limestone Series were examined. In these the "Crease" and "Whitehead" Limestones were shown, and resting on the latter in the Morse railway-cutting at Drybrook came the Millstone Grit.

Leaving Drybrook, the party turned in the direction of Mitcheldean, where the Wilderness Cement Works were to be visited. On the way some further beds of Millstone Grit were pointed out. They were of special interest inasmuch as they greatly resembled the Old Red Conglomerate in lithological structure, containing "veinstone" quartz pebbles which could not be distinguished from those in the Old Red Conglomerate.

Mr. Colchester-Wemyss now took the lead, and conducted the geologists to the Wilderness Cement Works, Limited, of which he is the Chairman. On arriving there it was discovered that Mr. and Mrs. Colchester-Wemyss had provided hospitality in the shape of a substantial tea. The refreshment having been partaken of and the hospitality acknowledged by the President, Mr. Colchester-Wemyss conducted the party over the quarries in which the Limestone is worked for making cement. These were all in the Upper Series, that is to say, in the Crease and Whitehead Limestones.

From the Cement Works the party proceeded to Mitcheldean Station, whence they returned by rail to the headquarters at Gloucester.

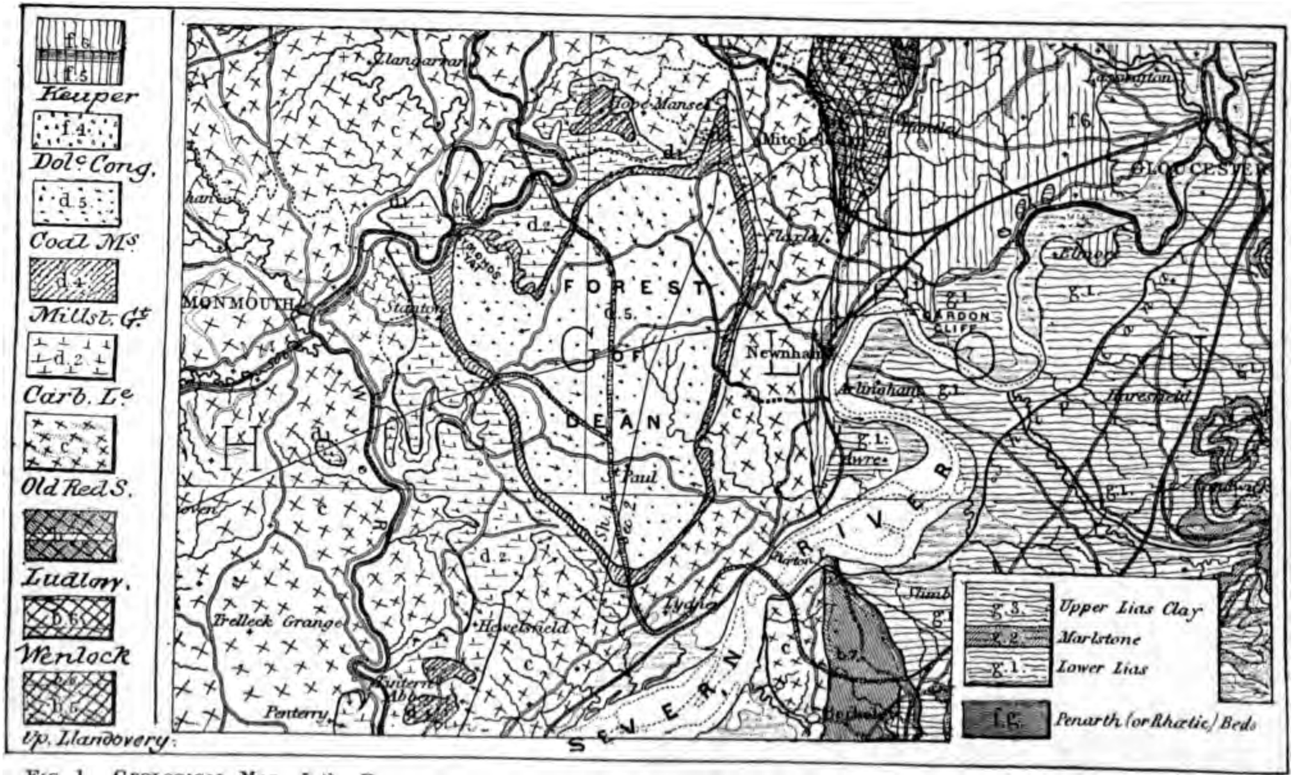


FIG. 1.—GEOLOGICAL MAP of the FOREST OF DEAN and part of the WYE VALLEY, including the country visited on Monday, August 6 (N.E. of the Forest of Dean), Tuesday, August 7 (Westbury-on-Severn and May Hill), and Wednesday, August 8 (Wye Valley). Scale, four miles to one inch.—From the *Geological Survey Maps.*

Tuesday.—A journey of eleven miles on the South Wales Railway carried the geologists from Gloucester to Newnham. The line first crosses Olney Isle, an alluvial flat enclosed by two arms of the Severn. Telford's graceful one-arch road-bridge over the west arm attracted attention. The rail runs on the Lower Lias to Churcham, and then on the New Red Marl to Newnham.

At Newnham Station they were met by Mr. Gwinnell, who acted as conductor during the day. From a neighbouring bridge he pointed out the Keuper Sandstone, which is well exposed in the midst of the red marls in the railway cutting. The old Roman road from the Forest of Dean to the Severn Ferry was crossed, a heap of pseudo-volcanic material derived from the blast furnaces and laid here for road-metal attracting much attention on account of its structure, and especially by the presence of free sulphur, evidently due to changes subsequent to solidification of the slag. After a brief examination of a recent cutting in the marls, the party proceeded along the terrace gardens, where a good view was had of the position of the great N. to S. fault and the striking contrast in the scenery on either side of it, the Old Red rising steeply beyond the line of fracture and being capped on the distant ridge by Carboniferous strata.

Proceeding to the churchyard, situated on a vertical cliff of Red and Green Marl about 70 feet high, a splendid view was obtained of the great horse-shoe curve of the Severn, the Vale of Glo'ster, and the distant Cotteswolds. Here the Director described the topography and physiography, remarking especially on the erosive action of the stream and tides on the convex sides of its curve and the accumulation of alluvial deposits on the concave portions. The phenomena of the "bore," so well seen at this spot at spring tides, were also described.

The base of the cliff at the ferry was next examined and seen to consist of many thin strata of various tints of red, green, and grey marls, of very unequal hardness, and consequently weathering unequally, producing a series of ledges. A walk of one mile along the river bank brought the party to Broad Oak, where the Mountain Limestone from the Avon gorge, being landed there for road-metal, was examined.

Continuing along the river bank for another mile the

Bed, and especially by the Upper and Lower Pullastra Beds (the latter strongly ripple-marked, and though but a foot thick projecting as much as seven feet), were especially noticeable. While seated on the fallen blocks from this cornice, or perched high up on the face of the cliff, the party was photographed. The hammers of the geologists were found useful in cutting footholds on the headland, whose base was under water, and which had to be rounded to avoid a long detour. After taking refreshment at Westbury a two-mile walk to Grange Court Junction was made, and the train taken from thence to Longhope, crossing *en route* the great fault seen earlier, which here brings up the Silurian Beds against the New Red.

From Longhope Station the party proceeded up Huntley Hill, an outlying part of May Hill, first passing over the Upper Ludlow sandy shales, which yielded some slabs very thickly crowded with molluscan shells. A small quarry in a depression showed the Lower Ludlow Beds—yielding abundant encrinital joints, and polyzoa—resting on the Wenlock Limestone with corals. A further ascent brought the party to a grand exposure of the Wenlock Limestone in a series of connected quarries along the crest of the ridge. The Limestone was very compact, and largely made up of corals, and had an irregularly undulating upper surface, on which the Ludlow Shales reposed. These latter were remarkably undulating, and the Director broached the theory that they had perhaps been deposited in this way on the irregular surface of a coral reef, for such the Wenlock Limestone here appeared to have been. After securing some good rugose and other corals the hill was descended by another route, and the five o'clock train, specially stopped for the occasion, taken for Gloucester.

After dinner, and the customary thanks to the day's Director, a visit was made to the Glo'ster Museum, specially opened for the occasion, where Mr. Gwinnell drew attention to the objects of more especial interest, including the splendid series of Ammonites arranged in stratigraphical order by the late Dr. Thos. Wright and by Mr. W. C. Lucy.

In the course of the evening a brief address on 'The History and Architectural Features of Gloucester Cathedral' was given by Mr. J. W. Parker, M.A., with a view of preparing the party for their visit to this edifice on the following morning.

Wednesday.—An early visit was made to the Cathedral, where the party was received by the Dean, who explained the structure in detail. After leaving the Cathedral the geologists, under Mr. Gwinnell's guidance, left by the Midland Railway for Berkeley Road Station, where the carriage reserved for the party was slipped and joined to the local train. It proceeded *viâ* Sharpness Docks, crossing the Tortworth inlier of Silurian Rocks, the buried forest at Sharpness, and the Severn Bridge, the largest iron bridge in England. Lydney was reached at 11.40, and the train then proceeded through a defile into the Forest of Dean, which was crossed through its central part from south to north, many fine exposures of the coal-seams and thick Coal-Measure Sandstones being seen. The sylvan scenery was in many parts extremely beautiful. The watershed being pierced through a short tunnel, the beautiful coombe-like valley of the Lydbrook was descended, the Mountain Limestone rising grandly on either side.

At Lydbrook Junction, on the banks of the Wye, the party alighted. The Director, with the aid of a large map, explained the geology and scenic features of the districts already passed through, and proceeded to describe what was about to be visited, the magnificent upper gorge of the Wye, commencing just a mile beyond the spot. A two-mile walk through English Bicknor and over the Coldwell Rocks, with frequent pauses to step out on the precipitous promontories of Mountain Limestone and view the towers and pinnacles of rock, their bases clothed with trees and their sides with ivy, brought the party to Symond's Yat, and the unrivalled prospect from its summit, 500 feet high, of which 200 is sheer precipice. The day being all that could be desired a magnificent view was had, and the result of the combined work of running water, wind, and weather in forming the winding gorge was very apparent.

The train was taken in the afternoon for Tintern *viâ* Monmouth. At Tintern arrangements for tea had been kindly made by Mrs. Upfield Green, and after tea the party visited the ruins of the Abbey. Two hours later the train was again taken and Chepstow reached through the lower gorge of the Wye, which was crossed by Brunel's famous bridge. A large quarry in the Mountain Limestone here yielded some corals, and the Director pointed out Aust Cliff in the distance, celebrated for its Rhætic

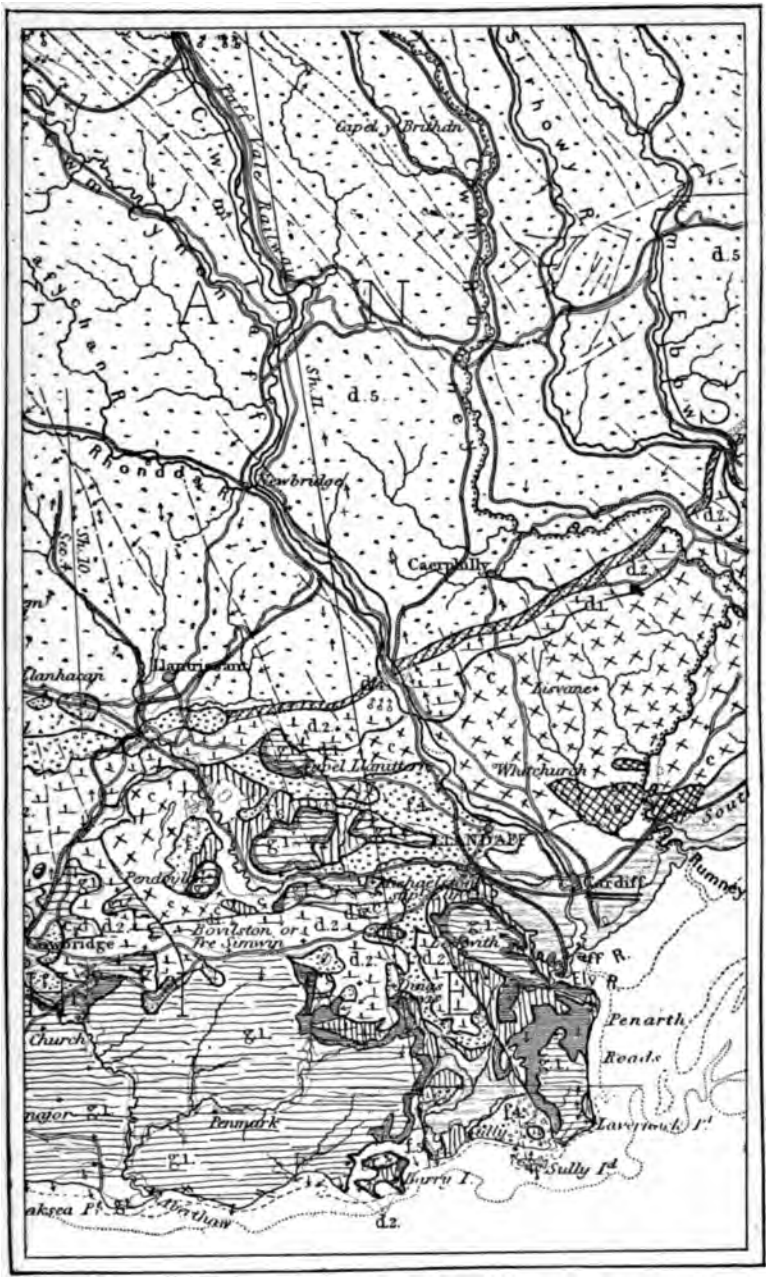


FIG. 3.—**GEOLOGICAL MAP** of the Neighbourhood of **CARDIFF** and part of the **SOUTH WALES COALFIELD**, including the country visited on Thursday, August 9 (Penarth and Rumney), Friday, August 10 (Taff Vale and Rhondda Valley), and Saturday, August 11 (Llandaff, Caerphilly, &c.). Scale, *four miles to one inch*.—From the Geological Survey Maps.

Section. Cardiff was reached *viâ* Newport about eight, the party proceeding to their quarters at the Park Hotel.

Thursday.—Under the guidance of Mr. T. H. Thomas and Mr. J. Storrie the party proceeded to Rumney, where they examined the Silurian Rocks described some years ago by Professor Sollas.* By means of two anticlinals the Silurian Strata are here brought up as inliers in the midst of the Old Red Sandstone. About 950 feet of Silurians, partly Wenlock and partly Ludlow, are exposed. Ty Mawr Quarry afforded an excellent section of the "Rumney Grit," a massive iron-stained quartzose sandstone. Casts of *Ctenodonta* were found in the yellow sandstone known as the *Discina* bed, and here, too, were obtained specimens of plant-remains, including *Pachytheca sphærica.* In Rumney Lane a coral bed was examined. Carriages were then taken to Roath Church, whence the party proceeded to Pen-y-lan Quarry. Here were exposed yellow and green mudstones with argillaceous sandstones weathering into spheroidal blocks. This quarry has yielded a large number of fossils, which serve to place the strata in the Wenlock Series, though the Llandovery facies of the fauna is admitted. *Petraia bina* and *Encrinurus punctatus* are abundant.

In Coed-y-gores Lane a folded section of the Silurian Rocks was seen, and numerous fragments of trilobites were obtained.

The section on the low bank of the Rumney River was then examined, the beds here containing Ludlow fossils and passing gradually upwards into the Old Red Sandstone. Immediately below the Old Red there occurs a brown grit containing spines of *Onchus tenuistriatus* and other fish-remains.† In the course of the morning the entire series of Rumney Silurian strata from the Wenlock to the base of the Old Red had thus been examined.

The party returned in carriages to Cardiff, and after luncheon proceeded by rail to the famous cliff-section at Penarth. The state of the tide was exceptionally favourable, and on the shore at Lavernock Point the beds were admirably exposed. The Lower Lias and the Rhætic Shales were well seen, and numerous organic relics obtained from the fish-bone bed.

---

* "On the Silurian District of Rhymney and Pen-y-lan, Cardiff," by W. J. Sollas, M.A., F.G.S., 'Quart. Journ. Geol. Soc.,' xxxv, 1879, p. 475.

† The fossils known as *Onchus* are probably fragments of Crustacea.—ED.

The walk under the cliffs from Lavernock to Penarth enabled the visitors to mark the succession of beds indicated by Mr. H. B. Woodward in the section given above at p. 530. Beneath the Rhætic Beds the New Red Marl, with its gypseous bands, was studied, and attention was specially directed to the faults which have disturbed the strata, and which in one place have caused the Rhætic Shale to be dropped down between Red Marls.

On reaching Penarth the party visited the art gallery at Turner House, where they were received by the proprietor, Mr. J. Pyke Thompson.

In the evening the Members of the Association attended a reception at the Museum to which they had been invited by the President and Committee of the Cardiff Naturalists' Society. On arriving at the Museum they found that arrangements for their comfort had been made on a most liberal scale, and a large party of local naturalists had assembled to greet them. The Museum collections, both scientific and artistic, were greatly admired, and the assemblage of local fossils was naturally a source of much interest. Prof. R. W. Atkinson, the Honorary Secretary of the Society, and Mr. J. Storrie, the Curator, were, with others, indefatigable in their attentions to the visitors. In the course of the evening congratulatory addresses were delivered by Mr. T. H. Thomas, the President, and by Dr. C. T. Vachell, who until recently had for many years acted as Honorary Secretary. Speeches were also made by the President of the Association and by Prof. Sollas, and at the conclusion of the meeting the general opinion was expressed that this social gathering was one of the pleasantest episodes of the Excursion.

Friday.—Mr. W. Galloway, a mining engineer of wide experience, and formerly one of the Government inspectors, met the geologists early on Friday morning, and acted as conductor during the day. Under his guidance they proceeded by the Taff Vale Railway to Havod Station, in the Rhondda Valley, and visited Lewis's Merthyr Colliery. Much interest was taken in the surface arrangements, the hoisting gear and ventilating fan being especially noteworthy. A large number of the party, under the guidance of the Manager and several other officers, descended the pit, and were taken through the principal workings. Both steam-coal and coking-coal are raised here from separate shafts. The new method of watering the underground roads by means of a spray to lay the coal-dust was shown in action. Mr. Galloway's long-continued researches on the influence of dust as a cause of colliery explosions are well known to all interested in the prevention of accidents.

Those who remained at the surface inspected the Welsh ovens in which coking is carried on, and witnessed the operations of coal-washing. They were afterwards joined by the visitors who had come up from the colliery, and the entire party sat down to a luncheon hospitably provided by the Directors of the Company, and presided over by Mr. W. H. Williams, the Chairman of the Company.

From Havod the visitors proceeded to Quakers' Yard Station, and were thence conveyed by special train to Harris's Navigation Colliery, where they were courteously received by Mr. Forster Brown, the Consulting Engineer. This colliery is the deepest in South Wales, and the machinery is of the most approved character. Much interest was taken in the surface appliances, but there was no time for a descent.

After partaking of light refreshment provided in the office. the party re-entered the special train and proceeded to Llanbradach, where they examined the sinking now being made by Mr. Galloway. This sinking is of interest to geologists from the fact that it is situated on the south of the great anticline, where the anticline itself has almost died out in passing eastwards. The mechanical arrangements attracted much attention, and the more adventurous of the party descended in the tub and saw the rock-drills at work. The water in this pit has been tubbed back with brickwork for the first time in South Wales.* Before leaving Llanbradach the party were entertained at tea by Mr. Galloway and a staff of ladies who had volunteered assistance, and decorated the offices for the reception of the party.

The special train was then taken to Pwllypant Quarry, where a deep section of the Pennant Sandstone Rocks is exposed. The train on proceeding homewards halted at the mouth of the tunnel in order that the exposure of the lowest seams in the

---

* "Sinking Appliances at Llanbradach," by W. Galloway. 'Proc. S. Wales Inst. Eng.,' xvi, 1888, p. 107.

South Wales Coalfield might be examined. The tunnel itself passes through the Carboniferous Limestone, and on the side nearer to Cardiff the Old Red Sandstone was seen.

As Friday evening was the last occasion on which the party would meet together at the dinner table, several speeches were delivered, and the hospitality of the Cardiff geologists duly acknowledged. An interesting function was the presentation of an address, signed by a large number of the Members, to Miss Mary Forster prior to her departure for Baltimore, U.S.A.

Saturday.—The programme for this day was arranged and carried out by Dr. C. T. Vachell, assisted by Mr. Storrie. Cardiff Castle, one of the residences of the Marquis of Bute, was first visited. Carriages were then taken to Llandaff, and the party was received at the Palace by the Bishop of Llandaff and Mrs. Lewis. The shaft of an ancient Celtic cross and the ruins of the old Palace were inspected. The party next proceeded to the Cathedral, and were conducted over the building by the Rev. Minor Canon Downing. The thoughts of the geologists naturally turned to Dr. Conybeare, who was at one time Dean of Llandaff, and whose monument is here.

William Daniel Conybeare was born in London in 1787. He was, in 1823, appointed Vicar of Sully, near Penarth, where he resided until 1836, when he removed to a family living at Axminster, and in 1845 he became Dean of Llandaff. With Buckland, he made a detailed study of the Bristol and South Wales Coalfields, the results of which were published in a paper of remarkable value considering the time of its publication. The two geologists also visited and described the coast of Antrim and Derry. We are indebted to Conybeare for an excellent account of the landslip at Axmouth in 1839, and for an exhaustive report on the position of geological science at the time the British Association was established. The 'Outlines of the Geology of England and Wales,' by Conybeare and W. Phillips, is well known. The versatility of Dean Conybeare's genius is also attested by his great palæontological knowledge and acute reasoning. In 1821 he established the genus *Plesiosaurus*, and so profound was his acquaintance with osteology that he was regarded by Cuvier as the founder of vertebrate palæontology in this country. Dean Conybeare died in 1845.

After visiting Conybeare's monument the party proceeded to the Deanery, where they were received by the Dean of Llandaff and Mrs. Vaughan. This pleasant visit ended, they rejoined their carriages and were taken to Radyr Quarry, where they found a good exposure of the Dolomitic Conglomerate.

The next object of interest visited was the Marquis of Bute's vineyard, where Mr. Pettigrew explained his system of grape cultivation.* Thence they passed to Castle Coch, recently restored by Lord Bute; and after luncheon visited the neighbouring quarries in which the Carboniferous Limestone is extensively worked.

The last feature in the programme was a visit to the Garth Mine, near Pentyrch, under the guidance of Mr. Stephen Vivian, of Llantrissant. The ore formerly worked in this mine is a mixture of Red and Brown Hematite, which occurs in irregular pockets in the Carboniferous Limestone. The mine has of late years been abandoned, but in view of the visit of the geologists the deserted workings had been inspected by the conductor. Furnished with lighted candles, the party now entered by a tunnel or adit-level, some 660 yards in length, driven through the solid Limestone. The ore had been worked below this tunnel, and was raised by means of an underground engine. Originally the workings were carried down from the crest of the Limestone hill, and the huge excavations thus made in the rock, which needed no timber for support of the sides, illuminated by daylight streaming down from above, formed a sight which is probably unique. Good specimens of ore and crystals of calcite were secured in abundance at this part of the mine. In the darker recesses of the workings water had accumulated in the deep cavities whence ore had been removed, and the Director tested the depth by casting great blocks of stone into the pools and listening to the noise of the fall as it reverberated through the subterranean galleries. When Mr. Vivian illuminated these chambers by means of coloured fires, the weird spectacle left an impression on the minds of the visitors not likely to be soon obliterated.†

---

* See "The Vineyard at Castle Coch," by A. Pettigrew. 'Trans. Cardiff Nat. Soc.,' xvi, 1884, p. 6.

† For description of the Garth Mine see Mr. Vivian's paper "The Hematite Deposits of the Southern Outcrop of the Carboniferous Limestone of South Wales," in 'Proc. S. Wales Inst., Eng.,' xiv, 1885, pp. 164-170. Also "On the Origin of the Hematite Deposits in the Carboniferous Limestone," by E. Wethered, 'Geol. Mag.' (ii), ix, 1882, p. 522.

On regaining the entrance to the adit, the explorers found themselves once more in the light of day. In due course the President acknowledged the assistance which had been so generously rendered by the numerous friends who had contributed to the success of the day's Excursion. And thus the week's work, which from first to last had been pleasant and successful, was brought to a formal conclusion, and the Members separated on the Saturday evening with the most satisfactory recollections of the Long Excursion of 1888.

REFERENCES.

Geological Survey Map, Sheets 43 S.W. and S.E. (Gloucester, May Hill, and Forest of Dean); 35 (S. part of Forest of Dean and Wye Valley); 36 (S. Wales Coalfield, Cardiff, and Penarth); 20 (Lavernock).

Geological Survey Index Map, Sheet 10. (This map, on a scale of four miles to the inch, will be found very convenient, as the single sheet includes the whole area visited.)

Horizontal Sections, Sheets 10, 11, 12, 13, and 15, illustrate the S. Wales Coalfield and Forest of Dean.

Vertical Sections, Sheet 47, Lower Lias and Rhætic or Penarth Beds of Glamorgan, etc.

ADAMS, W.—"On the Geological Features of the South Wales Coalfield," 'Journ. Iron and Steel Inst.,' Vol. i, p. 13.

BROWN, T. FORSTER.—"The South Wales Coalfield," 'Trans. S. Wales Inst. of Engineers,' ix, 1876, p. 59.

BUCKLAND and CONYBEARE.—"Observations on the South-western Coal District of England," 'Trans. Geol. Soc.,' ser. 2, Vol. i, p. 210.

Coal Commission Report, Vol. i, 1871. (S. Wales by Sir H. Hussey Vivian and Geo. T. Clark; Forest of Dean by J. Dickinson.)

DAVID, T. W. EDGEWORTH.—"On the evidence of Glacial Action in South Brecknockshire and East Glamorganshire," 'Quart. Journ. Geol. Soc.,' Vol. xxxix, p. 39.

DE LA BECHE, SIR H. T.—"On the Formation of the Rocks of South Wales and South-western England," 'Memoirs of the Geological Survey,' Vol. i, 1846.

ETHERIDGE, R.—"On the Rhætic Deposits of Penarth and Lavernock," 'Rep. Cardiff Nat. Soc.,' iii, 1872.

——— "On the Rhætic Beds at Garden Cliff," 'Proc. Cotteswold Nat. Field Club,' iii, 1865, p. 218.

GALLOWAY, W.—"On the Mode of Occurrence of Coal," 'Trans. Cardiff Nat. Soc.,' xvii, 1885, p. 20.

GLASS, REV. N.—"Silurian Strata near Cardiff," 'Geologist,' iv, 1861, p. 169.

GWINNELL, W. F.—"On the Rhætic Deposits of Britain," 'Proc. Athenæum Soc.,' 1886.

Harris, W. H.—"Geology of Cardiff," 'Science Gossip,' 1879, p. 99.

Harrison, W. Jerome.—'Geology of the Counties of England and of N. and S. Wales,' 1882. (Gloucestershire, p. 92; Monmouthshire, p. 178; S. Wales, p. 334.)

Hull, E.—'The Coalfields of Great Britain,' 4th ed., 1881. (S. Wales, p. 88; Forest of Dean, p. 125.)

Jones, John, and Lucy, W. C.—"Section of the Transition Beds of the Old Red Sandstone and Carboniferous Limestone at Drybrook in the Forest of Dean," 'Proc. Cotteswold Nat. Field Club,' iv, 1868, p. 175.

Meade, R.—'The Coal and Iron Industries of the United Kingdom, 1882.' (S. Wales, p. 188; Forest of Dean, p. 223.)

Murchison, Sir R. I.—'Siluria,' 4th ed., 1867.

Perkins, C. H.—"The Anthracite Coal and Coalfield of S. Wales," 'Report Brit. Assoc.,' 1880, p. 220.

Phillips, John.—"The Malvern Hills compared with the Palæozoic Districts of Abberley, Woolhope, May Hill, etc.," 'Mem. Geol. Surv.,' Vol. ii, Part 1, 1846.

Smyth, Sir W. W.—'Coal and Coal Mining,' 6th ed., 1886. (Forest of Dean, p. 67; S. Wales, p. 68.)

Sollas, W. J.—"On the Silurian District of Rhymney," 'Quart. Journ. Geol. Soc.,' xxxv, 1879, p. 475.

Symonds, Rev. W. S.—'Records of the Rocks,' 1872.

Wethered, E.—"On the Lower Carboniferous Rocks of the Forest of Dean," 'Quart. Journ. Geol. Soc.,' xxxix, 1883, p. 211.

——— "On a Section of Strata exposed in a Railway Cutting at Morse, near Drybrook," 'Proc. Cotteswold Nat. Field Club,' viii, 1886, p. 24.

Woodward, H. B.—'Geology of England and Wales,' 1887. (Forest of Dean, p. 191; South Wales Coalfield, p. 193; Rhætic Beds, p. 248; Drift, p. 493.)

INDEX.

PAGE
Abbott, G., elected ... 79
Abbott, W. J. L., Address by 39
„ on agates 80
Aberthaw Lime ... 534
Acanthopholis ... 285
Acrodontosaurus ... 313
Acrodus ... 289, 290
Acrognathus ... 323
Acrotemnus faba ... 308
Actinocrinus ... 19
Actinometra ... 20, 25
Agassiz on British Glaciers... 246
„ Fossil Fishes ... 262
Agassizocrinus ... 25
Agates, W. J. L. Abbott on 80
Algæ, Demonstration on Fossil ... 468
Algæ from Coal Measures ... 469
Algoid markings ... 468
Altar Stones, Ash from ... 484
America, Edentata of ... 457
Amphibia, Palæozoic ... 424
Ampthill Clay ... 447
Ancistrodon ... 330
Annual General Meeting, 1887 29
„ „ „ 1888 345
Antedon ... 20, 25
Antiquity of Man ... 247
Apatite, Artificial ... 209
Apiocrinidæ ... 23, 24
Apocopodon ... 297
Arca ... 392
Archæan, Graphite in ... 468
„ Group recognized 233
Archæology, Prehistoric ... 250
Arcidæ ... 389
„ Palæozoic ... 385
Armadillos, Fossil ... 458
Ashby, Capt. W., elected ... 58
Aspidochelydæ ... 7
Association, History of the... 270
Atheca ... 6
Atherfield Clay ... 157
Aulolepis ... 323
Australia, Marsupialia of ... 457

PAGE
Australian Agates ... 82
Aylesbury, Excursion to ... 166
„ Limestone ... 170

Bagshot Outlier at Laindon 489
Balance-sheet for 1886 ... 37
„ „ 1887 ... 348
Ball, Dr. E. J., elected ... 233
Ballingdon visited ... 188
Barnett, A. K., on the Logan Rock ... 211
Barnwell Gravels, Mollusca of ... 355
Bather, F. B., elected ... 2
„ on Cephalopoda 354
Bathycrinus ... 24
Bedford, Excursion to ... 504
„ Waterworks ... 504
Bedfordshire, Clays of ... 446
„ Gault of ... 447
Belgium Beds above Chalk... 55
Bell, Robert W., death of ... 206
„ „ on St. Erth Beds ... 206
Belonostomus ... 305
Bennett, F. J., on Early Settlements ... 361, 372
Berry, E. E., elected ... 79
„ J., elected ... 79
Berycopsis ... 328
Beryx ... 326
Bettongia ... 463
Billing, Dr. A., quoted ... 81
Bills, Mr. Whitaker on ... 140
Binney, E., on *Sigillaria* ... 263
Birdlip visited ... 157
Birds, Flightless, Demonstration on ... 457
Birds, Primal ... 422
Bishopstoke visited ... 134
Blackheath Pebble-bed 43, 49, 55, 192
Blackmore, G. F., elected ... 79
Blake, Prof. J. F., on Mount Sorrel ... 474
Blanch, G. E., elected ... 339

PAGE
Blastoids, Dr. P. H. Carpenter on ... 19, 25
Blown Sand ... 205
Boettger, Dr., on *Clausilia pumila* ... 357
Bolitho, Messrs., Tin-Smelting Works of ... 211
Bolton, H., elected .. 38
Bone-caves, Dr. Hickson ... 14
Bonney, Prof. T. G., quoted 72, 74
„ on Mount Sorrel Basalt ... 481
„ on Sharpley Rock... 475
Bonney and Hill on Charnwood Rocks ... 472
Borings, Deep ... 256
Boring, Jubilee, proposed ... 256
„ Sub-Wealden ... 256
Botallack visited ... 212
Botanical Department, British Museum, Visit to ... 468
Boucher de Perthes on Somme Gravels ... 248
Boulder Clay ... 449
Bourgueticrinus ... 24
Bowerbank, J. S. ... 241
Brander, Gustavus, and his Hordwell collection ... 124
Brandon flint-knapping ... 374
Brazil Wood Rock ... 481
Brent, Excursion to the valley of the ... 148
Brick-making ... 505
Brighton, Excursion to ... 141
Brindley, W., elected ... 354
Bristow, H. W., on the Penarth Beds ... 529
British Museum, Growth of... 267
„ Types in ... 331
„ Visit to 123, 457, 468
Brixham Cave ... 248
Brough, B. H., elected ... 233
Brown, George D., death of 29
„ J. Allen, collection of implements 181
„ „ on Southall implements 361
Buckland, Dean, 'Bridgewater Treatise'... 261
„ explores Kirkdale Cave ... 247
„ recognizes Scotch glaciation ... 246
Burrows, H. W., elected ... 18
Bursledon ... 136
Bury St. Edmunds visited ... 191
Butler, G. W., elected ... 445

PAGE
Cae Gwyn Cave ... 14, 16
Calamopleurus ... 324
Cambrian, The term proposed 242
Cameron, A. C. G., on brick-making .. 505
„ on Clays of Bedfordshire ... 446
Canterbury district, Eocenes of ... 45
Capellini, Prof. G., quoted... 10
Carboniferous Limestone, Analysis of ... 516
Carboniferous Limestone, Blastoids of ... 26
Carboniferous Rocks of Forest of Dean ... 510, 527
Cardiff, Reception at ... 551
Carclaze Mine ... 198
Carclayzite ... 200
Carn Brea ... 204
Carne Museum ... 212
Carpenter, Dr. P. H., on Crinoids and Blastoids ... 19
Carpenter, G. H., elected ... 79
„ W. Lant, Address by ... 39
Carruthers, W., on Fossil Algæ ... 468
Cartography ... 250
Castrocane, Count, on Diatoms from Coal-Measures 470
Catastrophists ... 236
Cates, A., elected ... 58
Caturus ... 306
Cave-deposits of the Wye ... 528
Cave mammals ... 18
Cerney, South, Kellaway's Rock at ... 159
Cestracion ... 289
Chalcedony ... 85
Chalk-mud silicified ... 219
Chalk, Vertebrata of ... 273
Champernowne, A., elected... 2
„ Obituary of 345
Chapman, F., elected ... 18, 272
Charlesworth, E. ... 241
Charnwood Forest, Excursion to ... 472
„ „ Rocks of 476
Chelone ... 5, 274
Chelonia ... 2
Chelonians of the Chalk ... 274
Chelytherium ... 3
Chimæra furcata ... 331
Chimæroidei ... 299
China-clay 111, 199, 200
China-stone ... 111
Chorley Wood Kiln ... 499, 500

PAGE
Chyandour Tin-Smelting Works ... 212
Cimolichthys ... 316
Cimoliochelys ... 275
Cimoliornis ... 283
Cirencester, Excursion to ... 157
Cladocyclus ... 325
Clandon Well-Section ... 185
Clapham Church ... 508
„ Excursion to ... 504
Claremont, C., elected ... 38
Clays of Bedfordshire ... 446
Clinker Tor Serpentine ... 196
Clupeoid Fishes ... 324
Clwyd, Vale of, Caverns in ... 14
Coal-Measures of Forest of Dean ... 527
Coal, Origin of ... 264
Coast-erosion at Selsea ... 138
Coccoderma ... 303
Cœlacanthus ... 302
Cœlodus ... 307
Cœlorhynchus ... 329
Coleman, Rev. W. H. ... 472
Collins, J. H., on Geology of Cornwall ... 94
Comatula ... 20, 21
Congress, International Geological ... 271, 354
Coniosaurus ... 282
Contact-metamorphism 208, 212, 483
Conversazione ... 38, 201
Conybeare and Phillips ... 254
„ Dean ... 533
„ „ Life of ... 553
Cookworthy discovers China-Clay ... 199
Coombe Rock ... 142
Cooper, T., elected ... 93
Cope, Prof. E. D., quoted ... 6, 9
Copper-ores ... 213
Corax ... 292
Cornish Heath indicative of Serpentine ... 214
Cornish Minerals ... 197
Cornwall, Excursion to ... 196
„ Geology of ... 94
„ Igneous Rocks ... 69
„ Mineral production of ... 113
Cosmogony ... 240
Cotylecrinus ... 25
Crag age of Lenham Sands... 183
„ at Sudbury ... 189
Crease Limestone ... 518, 543
Cretaceous Chelonia 3, 9, 10, 11
„ Crinoids ... 24

PAGE
Crick, G. C., elected ... 38
Crinoids, Dr. P. H. Carpenter on ... 19
Cross, Miss C. E., elected ... 272
Crossopterygian Ganoids ... 302
Croydon, Eocenes at ... 43
Cryptodira ... 6
Ctenodonta ... 395
Cucullæa ... 393
Cucullella ... 398
Culm Rocks ... 242
Cumberland, Gypsum in ... 435
Cundell, W. H., elected ... 445
Cuvier, Death of ... 261
Cyathidium ... 25
Cyathocrinus ... 19, 22
Cycnorhamphus ... 408
Cystids ... 20

Dagham stone ... 160
Dale, J. W., elected ... 58
Dana, J. D., on Agates, quoted 90
Daptinus ... 312
Darwin, Influence of ... 266
„ on Coral Formations 267
„ on formation of mould ... 267
Darwin, W. E., elected ... 385
Daubrée quoted ... 201, 208
Davidia ... 390
Davidson Collection of Brachiopoda ... 129
Davies, W., quoted ... 18
Dawson, Sir J. W., on Archæan graphite ... 468
Deep-sea exploration ... 256
De la Beche, Sir Henry ... 252
„ on Clifton section 511
„ on Forest of Dean ... 511
„ on Forest Iron-ore ... 517
Delft ware ... 130
Dendrocrinus ... 26
Dercetis ... 318
Dermodactylus ... 418
Dermatochelydæ ... 7
Dermatochelys ... 8
Devonian, The term proposed 243
Devon Igneous Rocks ... 69
Dewick, Rev. E. S., on Barnwell Mollusca ... 355
Dew-Ponds ... 377
Diatomaceæ, Fossil ... 470
Dick, A. B., on Sulphuric Acid 439
Diculafait, on Evaporation of Sea-Water ... 441
Dimorphodon ... 414

PAGE
Dinosauria of the Chalk ... 285
Dolcoath ... 204
Dolichosaurus ... 281
Dollis Hill visited ... 150, 178
Dollo, M., quoted ... 7
Dorygnathus ... 416
Douglas, M. H., elected ... 39
Doulton Potteries, Visit to ... 130
Doulton, Sir Henry, Address by ... 130
Downs, Chalk ... 373
Drepanephorus ... 288, 290
Drift at Ballingdon ... 188
" contorted at Sudbury 188, 189
Drybrook Section ... 543
Dry Valleys, J. Hopkinson on 500
Dudbridge ... 160
Duncan, Prof. P. M., on Uniformitarianism ... 238
Duporth Stone ... 202
Dyer, W. T. T., on Solenhofen Algæ ... 469

Ealing, Excursion to ... 172
" Drift at ... 174
East, G. E., jun., elected ... 38
Edaphodon ... 299, 300
Eden, Gypsum in valley of the 436, 438
Edentata, Demonstration on 457
Edmunds, J., elected ... 2
Edriocrinus ... 25
Edwards, F. E., Eocene Mollusca of ... 128
Ehrenberg on Micro-Organisms ... 261
Elasmodectes ... 299, 301
Elasmognathus ... 299, 301
Elephant-bed at Brighton ... 142
Elephas with implements ... 361
Elopopsis ... 324
Elvans ... 98
Emys Benstedi ... 275
Enchodus ... 315
Encrinus ... 22
Engineering, Geology and ... 255
Eocene Conditions ... 119
" Chelonians ... 3, 11
" Crinoids ... 24
" The term adopted ... 241
Eocenes, Classification of ... 49, 122
" , Lower, G. F. Harris on ... 40
Erith, H. G., elected ... 58
Etheridge, R., quoted ... 12
" on the Penarth beds 529, 535
Evans, Caleb, Obituary of ... 29
Evans, E., elected ... 385
Evans, Dr. John, quoted ... 223, 248

PAGE
Evolutionism ... 239
Excursions in 1886 ... 33
" 1887 ... 350
Extracrinus ... 23

Falconer, Dr. Hugh, at Brixham and Abbeville ... 248
Faulted junction of Gault and Folkestone Sands ... 156
Fawcett, W., resigns Council 35
Fenton, C., elected ... 354
Ffynnon, Beuno Cave ... 15
Finchley Deposits ... 176
Firestone at Godstone ... 496
Fisher, Rev. O., on Mountain Chains ... 473
Fishes of the Chalk ... 285
Flint ... 218
Flint-fracture ... 222
Flint Implements 16, 173, 181, 191, 224, 228, 248
Flint Implements at Southall 361
" " at Brandon 374
Flint-knapping ... 374
Flint Pebbles 79, 217, 226
Flint Sand never occurs ... 218
Flints, The un-making of ... 79, 217
Fluor ... 201
Folkestone Beds 156, 182, 497, 498
Foord, A. S., elected ... 385
Foraminifera in Flint ... 219
Forchammer on Sea Water... 220
Forest of Dean Carboniferous Rocks of ... 510, 527
Forest of Dean, Economic Products ... 523
Forest of Dean, Excursion to 542
" " Formations in 522
" " Fossils of ... 515
" " Geology of ... 522
" " Iron Ore in... 517
Forster, Miss, Presentation to 553
Foster, Dr. C. Le Neve, on Cornish Mining ... 205
Foulerton, Dr., Partial retirement of ... 35
Foulerton, Dr., Presentation to ... 93
Fox, C., elected ... 18
Freeland, P. W., Death of ... 29
French, H. H., on Sands of doubtful age ... 182
Frosterley Marble ... 203
Furnival, C. H., elected ... 93

Galloway, Rev. W. B., elected 93
Galloway, S., Death of ... 345
Galloway, W., on Anthracite 541

PAGE
Ganoidei ... 301
Garden Cliff ... 524, 546
Gardiner, Miss M. I., elected 385
Gardner, J. Starkie, quoted 50, 51, 57
Gardner, J. Starkie, on the London Clay ... 115
Garth Mine visited ... 554
Gault at Godstone ... 497
„ of Bedfordshire ... 447
Geikie, Dr. A., elected Honorary Member ... 352
Geikie, Dr. A., quoted ... 83
Geological Department, British Museum, Visit to ... 457
Geological Survey, Origin of 252
Geology, Fifty years' progress in ... 233
Gervais, P., quoted ... 6
Gibbs, A. E., elected ... 233
Gilbertson Collection ... 127
Glacial Controversy ... 245
Glacial Drift ... 188, 189
Glamorganshire, Rhætic and Lias of ... 529
Gloucester Cathedral, Mr. J. Parker on ... 547
Gloucester Cathedral visited 548
Gloucester Museum visited... 547
Gloucestershire Coal-fields... 510
Glyptarca ... 399
Glyptodon ... 459
Godstone, Excursion to ... 496
Godwin-Austen explores Kent's Cavern ... 248
Gold in Wales ... 339
Gold, Mode of Occurrence of 342
Gold-mine in Bedfordshire... 454
Gomshall, Excursion to ... 182
„ Section at ... 182
Goodchild, J. G., on Boulder Clay of Finchley ... 146
Goodchild, J. G., on Gypsum 424, 425
Goodchild, J. G., on Thanet Sand fauna ... 193
Goodchild, J. G., quoted ... 54
Gordon, R. M., elected ... 2
Granatocrinus ... 26
Granite, Formation under pressure ... 99
Granite, Kaolinisation of ... 201
„ Mount Sorrel ... 479
„ of Cornwall ... 94
„ Veins ... 208
„ Weathering of ... 204, 211
Grant, J. H., elected ... 233
Graphite in Archæan ... 468
Graphularia Wetherellii ... 195

PAGE
Grauwacke ... 241
Gravel at Ealing ... 175
Greatheed, W., elected ... 424
Green, Upfield, elected ... 1
Greenly, G., elected ... 354
Greenough, G. B. ... 235
„ his Map... 251
Greensand, Upper, Nodules in 154
Greenstones ... 69, 70
Greenwell, Canon, on Brandon 374
Greisen ... 208
Grenelle Well ... 255
Griffiths, C. R., elected ... 18
Griffiths' Map of Ireland ... 251
Groby Syenite ... 477
Growan Clay ... 200
Gwinnell, W. F., elected ... 79
Gwinnell, W. F., on Forest of Dean ... 522, 545
Gwinnell, W. F., on the Long Excursion ... 445
Gypsum, Natural History of 425
„ Origin of ... 439
Gyrodus ... 307, 308

Haddock, Canon, on Clapham Church ... 508
Haidinger, on Agates, quoted 90
Hampstead Heath visited ... 151
Hand-borer ... 471
Hansford, C., elected ... 1
Harding, Miss A. K., elected 2
Harker, Prof. Allen, on the Kellaway's Rock ... 159
Harley, Dr. George, on Agates, quoted ... 88
Harris, G. F., on Lower Eocenes ... 40
Harris's Navigation Colliery visited ... 552
Harrison, F., elected ... 2
Harrison, W. J., his Geology of the Counties ... 254
Hartwell Clay ... 167
„ „ Fossils ... 169
Hatch, Dr. F. H., elected ... 39
Hawkshaw, Sir John, discovers erect tree ... 263
Hayden, Dr. F. V., Obituary of ... 345
Hebridean, The term employed ... 244
Hematite, E. Wethered on ... 517
Hendon Drainage Works ... 151
Henslow, J. S., on Flint-fracture ... 223
Herne Bay district, Eocenes of ... 45

PAGE
Herries, R. S., elected ... 1
Hertfordshire, Geology of ... 165
Hicks, Dr. H., on Pre-Glacial Man ... 249
Hicks, Dr. H., on St. David's Rocks ... 244
Hicks, Dr. H., on Welsh Bone-Caves ... 2, 14
Highlands, Scottish ... 245
Hill and Bonney, Messrs., on Charnwood Rocks ... 472
Hill, Rev. E., elected ... 58
„ on Charnwood Volcanic Series ... 475
Hind, H. R., elected ... 354
Hind, Dr. W., elected ... 354
Hinde, Dr. G. J., on Chert, quoted ... 221
Hinde, Dr. G. J., on Upper Greensand Nodules ... 154
Historical Collections at British Museum ... 123
Hoddinott, H. E., elected ... 38
Hoff, Von, quoted ... 236
Holaster pillula ... 132
Holl, Dr., on Malvern Rocks 244
Hollow ways ... 382
Holme, C., elected ... 2
Holopus ... 24
Homonotus ... 329
Hook Wood, Section at ... 185
Hopkinson, J., on Geology of Herts ... 165
Hoplopteryx ... 327
Hordwell, Brander Collection from ... 124
Horsington Hill visited ... 180
Hotson, A., elected ... 339
Hudleston, W. H., on Kimeridge Clay ... 168
Hudleston, W. H., on Nodules 471
„ on Portlandian Rocks ... 169
Hughes, Prof. T. Mc K., on Flint-fracture ... 223
Hunt, Dr. Sterry, on Origin of Gypsum ... 440
Huttonian Controversy ... 235
Hutton's "Theory" ... 239, 271
Huxley, Prof. T. H., on Evolutionism ... 239
Huxley, Prof. T. H., on *Hypotheria* ... 422
Hybodus ... 287
Hydrofluoric Acid acting on Granite ... 201
Hypotheria ... 422
Hypsodon ... 314, 325

PAGE
I'Anson and Pankhurst's Experiments on Silica ... 84, 91
Ichthyodectes ... 311
Ichthyosaurus ... 278
"Ink, Prehistoric" ... 135
International Geological Congress ... 271, 354
Iron Ore in Forest of Dean 517
Irving, Rev. A., on Bagshots 184
Ischyodus ... 299, 300
Isis ... 19, 23

James, Sir Henry, quoted ... 197
Jameson, Prof. ... 235
Jasper ... 86
Johnston, J. N., elected ... 18
Jones, H. E., elected ... 58
Jones, Prof. T. Rupert, quoted 217
Jubilee Boring proposed ... 256
Judd, Prof. J. W., on Flints 79, 217
Jukes-Browne on Deep Ploughing ... 451
Jukes on Charnwood Forest 472
Jurassic Chelonians ... 8
„ Crinoids ... 23, 24

Kaolin ... 199
Kaolinisation ... 201
Keay, A., elected ... 93
Kellaway's Rock 158, 159, 454
„ Fossils of ... 159
Kent's Cavern ... 248
Killas ... 95
Kimeridge Clay ... 168
Kingsbury Church ... 149
Kingston, T., jun., elected ... 79
Kirkdale Cave ... 247
König, Charles, Types of ... 127
Kynance Cove ... 214
Kynaston, H., elected ... 361

Lahontan, Lake ... 440
Laindon Church ... 493
Laindon Hills, Excursion to 489
Lamellibranchiata, The term 387
„ Classification of ... 387
Lamna ... 290
Land's End visited ... 211
Lange, on Agates, quoted ... 89
Lapworth, Prof., on the Highlands ... 244
Laurentian, The term proposed ... 243
Lavernock ... 533, 550
Leiodon ... 279, 280
Lenham Sands ... 183
Leonard, J. H., elected ... 18

PAGE
Lepidenteron ... 319
Lepidotus punctatus ... 304
Leptacanthus ... 300
Leptotrachelus ... 319
Lewisham, Eocenes at ... 43
Lewisian, The term employed 244
Lias Conglomerate ... 535
Lias at Dudbridge visited ... 160
Liassic Crinoids ... 20, 23
Lindley and Hutton's Fossil Flora ... 264
Literature, Geological ... 253
Litton, R. T., elected ... 79
Lizard, Rocks of the ... 72
Lizard Serpentine ... 201, 214
Lizard visited ... 214
Llanbradach visited ... 552
Llandaff visited ... 553
Llandovery Fossils ... 526
Loampit Hill, Excursion to 501
Lobley, J. Logan, on Flint Pebbles ... 79, 226
Lobley, J. Logan, on Palæozoic Arcidæ ... 385
Locke, E., elected ... 18
„ on Merstham Church 155
Lodes ... 101, 105
Logan, Sir W., on Underclay 264
„ proposes "Laurentian" ... 243
Logan Rock ... 211
London Basin ... 40
London Clay at Earley ... 494
„ Boring in .. 489
„ Club ... 128
„ Depth at which formed ... 118
London Clay, Fauna of 118, 181, 195
„ Landscape ... 148
„ Notes on ... 115
Lonsdale ... 242, 262
Lophiostomus ... 303
Lucy, W. C., and John Jones on Drybrook Section ... 513
Luff, T. C., elected ... 38
Lydekker on Fossil Marsupials ... 467
Lyell, Sir C., publishes his "Principles" ... 237
Lyell, Sir C., quoted ... 369

Macculloch, Dr. John, his map of Scotland ... 251
Macelognatha ... 8
MacEnery, Rev. Father ... 248
Mackie, S. J., quoted ... 223
Macleay, W. S., on *Thylacoleo* 463
McLeod, Miss J. B., elected 2

PAGE
McMahon, Col. C. A., elected 38
„ Major-General, on Charnwood Rocks ... 476
Macrocystella ... 26
Macrodon ... 394
Macropoma ... 302
Macropus ... 464
Macrotherium ... 460
Malvern Rocks ... 244
Mammalia in Welsh caves... 18
„ Origin of ... 422, 423
Mammoth in Thames Valley 361
Man and the Ice age ... 249
„ Antiquity of ... 247
„ Preglacial ... 18
Marazion visited ... 207
Marden Park ... 496
Marsh, Prof. O. C., quoted... 8
„ on primal birds ... 422
Marsupials, Classification of 461
„ List of Fossil ... 465
„ Demonstration on 457, 460
Mastoid fracture of flint ... 223
May, F., elected ... 385
May Hill ... 526, 547
Medal offered by Mr. Whitaker 134
Megatheriida ... 457
Menevian Beds, *Protocystites* from ... 26
Merstham, Excursion to ... 154
Merthyr Colliery visited ... 551
Mesoblastus ... 26
Metamorphism, E. A. Wünsch on ... 201
Metamorphosis ... 58
Meyer, H. von, quoted ... 8
Microdon ... 308, 326
Miers, H. A., elected ... 272
Miller, Hugh ... 243, 262
„ J. S., quoted ... 19
Millett, Fortescue W., on St. Erth Fossils ... 207
Millstone Grit ... 520
„ Analyses of... 521
Minear Downs ... 199
Miocene Chelonians ... 12
„ The term adopted... 241
Mitcheldeania ... 514
Mitchell, C. J., elected ... 2
„ P. C. ... 79
Moggridge, M., on Beach-action ... 229
Mollusca of Barnwell Gravels 355
Monckton, G. F., elected ... 272
Mond, R. L., elected ... 385
Moor Park visited ... 165
Morris, John ... 262
„ his 'Catalogue' ... 263

PAGE
Mosasaurus 11, 279, 313
„ *gracilis* ... 313
Mount Sorrel Basalt ... 480
„ Granite ... 479
„ visited ... 473
Murchison, Sir R. ... 242
„ quoted ... 340
Museum, British, Visit to ... 457, 468
„ of Practical Geology, History of ... 268
Museums ... 267
„ visited in 1886 ... 32
„ „ 1887 ... 350
Myliobatis ... 297
Mylodon ... 458
Myrmecophaga ... 457

Nathorst, Dr., on Algoid markings ... 468
Natural History Museum, Visit to ... 457, 468
Nematophycus ... 469
Neorhombolepis ... 304
Netherfield, Gypsum at ... 431
Netley railway-cutting ... 135
Newhaven visited ... 143
Newnham visited ... 545
Newton, E. T., on Pterodactyls ... 385, 406
Nicholson, Prof. H. A., on *Mitcheldeania* ... 515
Notidanus ... 287
Nucula ... 401
Nyctodactylus ... 420

Oak-tree Clay, Smith's mistake as to ... 154
Oberstein, Agate-industry at 81
Obituary ... 29, 345
A. Champernowne ... 345
Caleb Evans ... 29
F. V. Hayden ... 345
Odontaspis ... 291
Oldhamia ... 469
Oldhaven Sand 49, 50, 56, 117, 192
Old Red Conglomerate ... 542
„ Sandstone ... 243
Oligocene Chelonian ... 13
Olivine ... 64
Oolites at Bedford ... 505
Opal ... 86
Ornithocheirus ... 283, 417
Ornithopterus ... 420
Ornithostoma ... 418
Osborn, Prof., on Fossil Marsupials ... 467

PAGE
Osmeroides ... 322
„ *levesiensis* ... 318
Ostracion ... 12
Ostracoda of Forest of Dean 516
Otodus ... 291
Owen, E. Lloyd, elected ... 1
„ George ... 541
„ Prof. Sir R., his osteological work ... 261
Oxford Clay ... 449
„ Analysis of ... 508
„ Fossils of ... 453
Oxyrhina ... 290

Pachyrhizodus ... 313
Pagham Harbour ... 139
Palæarca ... 400
Palæobotany, Progress of ... 263
Palæontographical Society... 128, 263
Palæontology of Lower Eocenes ... 46
Palæontology, Progress of... 265
Palæozoic Crinoids ... 20
Palæozoology, Progress of... 260
Pankhurst and I'Anson's experiments on Silica ... 84, 91
Papers read during 1886 ... 31
„ „ 1887 ... 349
Paragenesis, Daubrée on ... 209
Parker, Prof. W. K., on origin of Mammalia ... 423
Peal, C. N., elected ... 2
Pectunculus ... 386
Peldar Tor Rock ... 488
Pelecopterus ... 321
Pelecypoda, The term ... 387
Pelmatozoa ... 19
Peltochelydæ ... 7
Penarth ... 529
„ visited ... 551
Pengelly explores Devonshire caves ... 248
Pentacrinus ... 19, 21
Pentremites ... 26
Penzance visited ... 205
Permian, The term proposed 242
Petrology, Progress of ... 257
„ Decline of ... 258
Petuntzite ... 200
Phillips, J. A., quoted ... 66
„ Prof. J., quoted ... 127, 179
Philosophy, Geological, in 1837 ... 234
Pidgeon, D., elected ... 38
Pilgrim's Way ... 155
Pinner, Inlier at ... 165
Pipes and swallow-holes, J. Hopkinson on ... 500

PAGE
Pisolite at Crickley Hill ... 158
Plagioclase ... 61
Platax ... 326
Platycrinus ... 19
Plesiosaurus ... 277
Plethodus ... 331
Pleurodira ... 6
Plinthophorus ... 319
Pliocene age of Lenham Sands ... 813
„ Beds of St. Erth ... 206
„ Chelonian ... 13
„ , The term adopted... 241
Plumstead, Excursion to ... 191
Polyptychodon ... 276
Pomognathus ... 317
Porter, J., elected ... 272
Portheus ... 310
Portlandian Conglomerate ... 167, 169
Preglacial occupation of caves ... 18
“Prehistoric ink” ... 135
Presidential Address for 1887 233
Pressure-metamorphism ... 260
Prestwich, Prof., on antiquity of man ... 249
„ on uniformitarianism ... 238
„ quoted 40, 48, 49, 183
Prionolepis ... 306
Progress in British Geology 233
Protocystites ... 26
Protosphargis ... 10
Protosphyræna ... 320
Protostega ... 9, 10, 11
Prototaxites an Alga ... 469
Prouse, O. M. ... 471
Psephoderma ... 8
Psephophorus ... 4, 6, 13
Ptenodracon ... 411
Pteranodon ... 419
Pterodactyls ... 406
„ Skull and brain of ... 421
„ Affinities of ... 422
Pterodactylus ... 283
Pterosauria of the Chalk ... 283
Ptychodus ... 294
Putney, Excursion to ... 471
Pyroxene ... 63
Pythonomorpha ... 279

Quick, F. W., elected ... 93

Railways and Geology ... 255
Ramsay, A., on London Clay Mollusca ... 181

PAGE
Ramsay, Sir A., on Gloucestershire Coal-fields ... 510
Ramsay, Sir A., Gold in Wales ... 340
Rayner, F., elected ... 339
Reade, Commander, elected 2
Reading Beds ... 494, 499
Reading, Excursion to ... 493
Readwin, T. A., on Gold in Wales ... 339
Red Rocks ... 432
Reid, Clement, quoted ... 183
„ uses Hand-borer ... 471
Reigate Castle visited ... 156
Report for 1886 ... 29
„ 1887 ... 345
Reptiles of the Chalk ... 274
Rhacolepis ... 329
Rhætic Beds ... 524
„ „ of Glamorganshire ... 529
Rhætic Chelonians ... 8
Rhamphocephalus ... 416
Rhamphorhynchus ... 415
Rhaphiosaurus ... 281
Rhizocrinus ... 24
Rickmansworth, Excursion to ... 163, 499
Ridley, M. N., elected ... 38
Roads, Influence of Geology on 372, 377, 383
Rock-basins ... 204
Rocks, Igneous ... 58
Roman Cement ... 195
Roman Road-making ... 379
Roscoe, P., elected ... 39
Rose, C. B., on Flint-fracture, quoted ... 222
Rudler, F. W., Address by... 233
„ elected President ... 36
„ nominated as President ... 35
„ on South Wales Coal-field ... 538
„ re-elected ... 353
Rumney Silurian Rocks visited ... 550
Rumsey, Miss S. M., elected 272
Ruskin, J., on Agates, quoted 86, 87
Rust, Dr., on Radiolaria, quoted ... 221

St. Buryan visited ... 210
St. Erth visited ... 206
St. Just visited ... 212
St. Michael's Mount ... 208
Salter, J. W. ... 127

PAGE
Salt Manufacture in Hampshire ... 135
Sand in Clays ... 231
„ never Flint ... 218
Sands of Doubtful Age ... 183
Saporta, Count, quoted ... 468
Saurocephalus ... 316, 320
Saurodon ... 316
Scaphognathus ... 411
Scylliodus ... 293
Seaford visited ... 143
Sea-water, Evaporation of ... 441
Sedgwick, Prof. A. ... 241
Seeley, Prof. H. G., quoted... 6, 13
Selache ... 298
Selachii ... 286
Selenite ... 426
Selsea ... 139
Serpentine, Clinker Tor ... 196
Settlements, Influence of Geology on ... 361, 372
Sharman, J. E., elected ... 361
Sharpley Rock ... 475, 487
Sheppey, Excursion to ... 194
„ Fossils ... 195
Sich, H. W., elected ... 58
Silica ... 218
„ allotropism of ... 83
„ in Clays ... 231
„ in Sea-water ... 220
Siliceous Organisms ... 221
Silicified Wood, Agates in ... 82
Silurian, The term proposed 242
Simpson, T., elected ... 2
Skertchley, on Brandon Implements ... 249
"Slades" ... 193
Slag, Sulphur in ... 545
Sloane Collection ... 123
Smart, J. P., elected .. 2
Smith, William, his Maps ... 251
„ Life of ... 125
„ Collection of 124
Smyth, Sir W., on St. Michael's Mount ... 208
Social Geology ... 269
Society, History of Geological ... 269
Sollas, Prof., on *Oldhamia*... 469
Sorby, Dr. H. C., on Fluid-cavities, quoted ... 99
„ on Mount Sorrel Granite ... 479
„ quoted ... 217, 259
„ suggests micropetrology ... 259
Southall, *Elephas* and Implements at ... 361

PAGE
Southampton, Excursion to 132
„ Water-works 133
South Wales Coal-field ... 538
„ „ Excursion to ... 542
Sowerby Collection ... 126
Sphargis ... 3, 12
Spiers, Rev. W., elected ... 18
Spinax ... 288
Sporangites ... 514
Squatina ... 294
Stannard, A., on Section at Redbrook ... 513
Stenostoma ... 328
Stigmaria, Prof. Williamson on ... 263
Stockworks ... 104
Strahan, Mr., quoted ... 15
Straker, J., elected ... 93
Stratigraphical Geology, Progress of ... 240
Stratodus ... 314
Stream-works ... 104
Strophodus a Crustacean ... 293
Sub-Wealden Boring ... 256
Sudbury, Excursion to ... 187
Sullivan, Dr., on Agates, quoted ... 90
Surveying Expeditions ... 257
Sutton Stone ... 535
„ „ Fossils of ... 537
Swinstead, P. E., elected ... 445
Syenite, Groby ... 477
Syllæmus ... 325
Synechodus ... 287
Synonyms of Chalk Vertebrates ... 335

Tabor, Rev. R. S., elected ... 18
Teall, J. J. H., on Groby Syenite ... 477
Teall, J. J. H., on Metamorphosis of Igneous Rocks... 58
Teall, J. J. H., on Petrography ... 259, 260
Teall, J. J. H., on the Lizard ... 214
Tehidy Park, Banquet at ... 205
Teleostei ... 308
„ Classification of ... 309, 310
Terebratula bisinuata ... 138
Tertiary man ... 249
Tetrapterus minor ... 321
Thames Valley Deposits ... 179
Thanet Sands at Plumstead 191
„ „ at Sudbury... 188, 189
„ „ Fossils ... 191, 193
Thecophora ... 7

PAGE
Thiolliericrinus ... 24n
Thomas, W., elected ... 272
Thylacoleo not Carnivorous 462
Tilburstow Hill visited ... 497
Tin ... 197
Tin-smelting ... 211
Tin Stream-works ... 104
Tintern visited ... 548
Titaniferous Iron-ores ... 65
Tomognathus ... 312
Topaz .. 208
Topley, W., on Coast-erosion 1
Topley, W., on Geological Surveys ... 253
Topley, W., on International Congress ... 354
Topley, W., on Parish Boundaries ... 374
Topley, W., retires from Presidency ... 34
Trachichthys ... 329
Trail ... 194
Trias, Chelonia in ... 2, 3
Trionyx ... 4, 8
Truro Cathedral ... 201
„ visited ... 196
Turf intaglios ... 373
Turtles, Leathery ... 14
Type Collections in the British Museum ... 123

Uniformitarians ... 236
United States Survey, Director of, elected Hon. Member ... 352
Upnor District, Eocenes of... 44

Van Beneden, Prof. P. J., quoted ... 13
Veins, Intrusive, in Cornwall 97
Vertebrata of the Chalk ... 273, 331
„ „ „ Key to ... 336
Voelcker, Dr., Analysis of Oxford Clay, by ... 508

Wales, Gold in ... 339
Waterman, Miss E., elected 79
Watts, W. W., elected ... 1
Wealden Dinosaurian ... 9
Wealden, near Aylesbury ... 171
Weald, Forest of the ... 375
Well-borings and Geology ... 255
Wenlock Limestone ... 547
Wernerianism ... 235, 258
Westcombe Park, Excursion to ... 501

PAGE
Wethered, E., on Carboniferous Rocks ... 510
Wethered, E., on Old Red Conglomerate ... 542
Wethered, E., on the Forest of Dean ... 446
Wharton, H. T., elected .. 233
Whetstone, Excursion to ... 145
Whewell, Dr. W., quoted ... 237
Whitaker, W., Bronze Medal offered by ... 134
Whitaker, W., on Chorley Wood Kiln ... 500
Whitaker, W., quoted 41, 48, 49, 183
Whitehead Limestone ... 519, 543
Wight, G. P., elected ... 39
Willett, H., Types in collection of ... 332
Williamson, Prof. W. C., on Coal-measure Plants ... 264
Williamson, Prof. W. C., on *Stigmaria* ... 263
Wilson, J., elected ... 79
Wiltshire, E., Analysis of Carboniferous Limestone 516
Wimbledon, Excursion to ... 471
Winwood, Rev. H. H., elected 2
Witchell, Edwin, death of ... 163
„ on the Stroud District ... 160, 161
Wollaston Medals ... 261
Woodhatch, Neocomian Section at ... 157
Woodocrinus ... 25
Woodward, A. Smith, on Leathery Turtles ... 2
Woodward, A. Smith, on Vertebrates of Chalk ... 272, 273
Woodward, B. B., on Barnwell Mollusca ... 355
Woodward, B. B., Statistical Statement by ... 270
Woodward, Dr. Henry, Demonstration by ... 457
Woodward, H. B., his 'Geology of England' ... 254
Woodward, H. B., on Boulder Clay ... 145
Woodward, H. B., on Glamorganshire ... 445
Woodward, H. B., on Laindon Bagshots ... 490
Woodward, H. B., on Rhætic and Lias ... 529
Woodward, H. B., on Weathering of Chalk ... 450
Woolwich and Reading Series, Inlier of ... 165

PAGE
Woolwich and Reading Series, Leaves from ... 1
Woolwich Beds at Plumstead ... 191
Woolwich District, Eocenes of ... 43
Worth, R. N., on Truro Cathedral ... 202
Wünsch, E. A., Address by ... 201

PAGE
Wye Valley, Excursion to ... 542, 548

Xanthidium ... 470

Yardley, R. B., elected ... 2
Yellowstone Sinter Deposits 83
Young, A. C., elected ... 354
Young, Arthur, on Laindon 492

Zeuglodon ... 11

✓

49991